Office of the Associate Administrator
for Commercial Space Transportation (AST)
Federal Aviation Administration (FAA)
Department of Transportation (DOT)

VOLUME 1:
PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT FOR LICENSING LAUNCHES

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LIST OF ACRONYMS AND ABBREVIATIONS

A-50	Aerozine-50
AAM	Annual Arithmetic Mean
ACS	Attitude control system
Al_2O_3	Aluminum oxide
Ar	Argon
AST	Office of the Associate Administrator for Commercial Space Transportation
Ca	Calcium
CAA	Clean Air Act
CeTAP	Cetacean and Turtle Assessment Program
CEQ	Council on Environmental Quality
CFC	Chlorofluorocarbon
CFR	Code of Federal Regulations
Cl	Chlorine
cm	Centimeters
CO	Carbon monoxide
CO_2	Carbon dioxide
CSLA	Commercial Space Launch Act
CZMA	Coastal Zone Management Act
dB	Decibels
dBA	Decibels (A-weighted)
DOT	Department of Transportation
EA	Environmental Assessment
EPA	Environmental Protection Agency
EIS	Environmental Impact Statement
ELV	Expendable Launch Vehicle
FAA	Federal Aviation Administration
FRP	Fiber Reinforced Plastic
FSS	Flight Safety System
FTS	Flight Termination System
GEM	Graphite Epoxy Motor
GEO	Geosynchronous Earth Orbit
GTO	Geosynchronous Transfer Orbit
H	Atomic hydrogen
H_2	Hydrogen
HAP	Hazardous air pollutant
HCl	Hydrogen chloride
He	Helium
H_2O	Water
Hz	Hertz
IIP	Instantaneous Impact Point
K	Potassium
km	Kilometer
L_{dn}	Day-night noise level over a 24 hour period

LEO	Low Earth Orbit
LH_2	Liquefied hydrogen
LO_x	Liquefied oxygen
LV	Launch vehicle
MMH	Monomethylhydrazine
Mn	Manganese
N_2	Nitrogen
Na	Sodium
NAAQS	National Ambient Air Quality Standards
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Policy Act
NMHC	Nonmethane hydrocarbons
NO_x	Nitrogen oxides
NO_2	Nitrogen dioxide
N_2O	Nitrous oxide
N_2O_4	Nitrogen tetroxide
O	Atomic oxygen
O_2	Oxygen
O_3	Ozone
OSHA	Occupational Safety and Health Administration
P	Phosphorus
PBAN	Polybutadiene acrylonitrile
PEIS	Programmatic Environmental Impact Statement
Pb	Lead
$PM_{2.5}$	Particulate matter of 2.5 microns or less in diameter
PM_{10}	Particulate matter of 10 microns or less is diameter
ppm	Parts per million
psf	pounds per square foot (measure for overpressure)
REEDM	Rocket Exhaust Effluent Diffusion Model
RCRA	Resource Conservation and Recovery Act of 1976
RP1	Rocket Propellant 1 (Jet fuel)
RV	Reentry Vehicle
SLC	Space launch complex
SO_2	Sulfur dioxide
SPEGL	Short-term public emergency guidance level
SRM	Solid rocket motor
TLV	Threshold limit value
TTS	Thrust Termination System
µg/m3	Micrograms per cubic meter
UV	Ultraviolet
VAFB	Vandenberg Air Force Base
WSMR	White Sands Missile Range
Xe	Xenon
Zn	Zinc

EXECUTIVE SUMMARY

The FAA's office of the Associate Administrator for Commercial Space Transportation (AST) is responsible for issuing licenses for the launch of launch vehicles (LVs).[a] Issuing a launch license is considered a federal action and is subject to review as required by the National Environmental Policy Act (NEPA) of 1969, as amended, 42 U.S.C. 4321 et seq. This Programmatic Environmental Impact Statement (PEIS) evaluates the potential environmental consequences of licensed launches. It will be used by the FAA, in conjunction with other documentation, to assess the environmental impacts of licensed launches, and to support licensing of such operations. The primary commercial use for launches is placement of communication satellites in orbit; other examples of commercial uses of LVs are remote sensing and scientific research, such as materials processing in a microgravity environment. The demand for communication satellites has been steadily growing due to the increased demand for existing satellite services and new technologies (i.e., mobile communications services, and the next generation broadband interactive television and radio).

This PEIS covers licensed launches from both existing government launch facilities and non-federal launch sites. This PEIS will update and replace the FAA's 1986 Programmatic Environmental Assessment (EA), as announced in the Federal Register November 27, 1995 Notice of Intent. This PEIS assesses the potential environmental effects of launches from ignition, liftoff and ascent through the atmosphere to orbit, and the disposition of launch vehicle components down range. Any remaining launch processing (including vehicle assembly and payload preparation prior to liftoff, payload functioning during useful life, and payload reentry whether controlled or uncontrolled) are outside the scope of this PEIS.[b] The scope is limited to the assessment of environmental consequences of the launch operations listed; no construction activities (e.g., development of new launch sites or modification of existing ones) are assessed. The information in this PEIS is not intended to address all site-specific launch issues. Any required site-specific environmental documentation would be developed as needed. In addition, this PEIS does not include site-specific, localized effects. Localized effects and the cumulative impact of these localized effects at an individual launch site can only be appropriately analyzed in the environmental review of a launch site operator. Licensees are expected to comply with all applicable Federal, state, and local laws and regulations and international treaties. Licensees are required to comply with waste disposal regulations including the Resource Conservation and Recovery Act (RCRA) requirements. Environmental reviews in support of launch specific licenses address the environmental impacts associated with issuing a license for a single launch, or a specified number of identical launches, from a single launch site, while environmental reviews in support of launch operator licenses address the local and cumulative impact of launches from the specific site. Both types of reviews (i.e., launch licenses and launch operator licenses) are expected to tier from this PEIS in the future.

ES.1 The Preferred Alternative and Additional Alternatives

This PEIS analyzes the environmental impacts of the preferred alternative, licensing launches, and two alternatives. Licenses for launches would be issued in accordance with the specifications set out in 49 U.S.C. Subtitle IX—Commercial Space Transportation, ch. 701, Commercial Space Launch

[a] Launch vehicles (LVs) in this Programmatic Environmental Impact Statement are comprised of both expendable launch vehicles (ELVs) that have stages or components that are not intended for recovery or reuse, and reusable launch vehicles (RLVs) that have stages or components that can return to Earth and be recovered and reused.
[b] The payload is the item that an aircraft or rocket carries over and above what is necessary for the operation of the vehicle in flight.

Activities, 49 U.S.C. §§ 70101 – 70121, and supporting regulations. The licensing of launches is considered a major federal action and is therefore subject to NEPA review. As part of this review process five alternatives were considered to the preferred alternative. Three of these alternatives are not specifically addressed in this PEIS because they were determined to be not feasible. The other two alternatives include more environmentally-friendly propellant combinations alternative and a no action alternative. Under the more environmentally-friendly propellant combinations alternative, the FAA would emphasize licensing launches using LVs that produce fewer air emissions of concern. Under the no action alternative, the FAA would not issue licenses for launches. This PEIS analyzes environmental impacts by examining the following characteristics of LVs and LV launch profiles:

- payload capacity (the mass an LV can lift into a particular orbit),
- types of propulsion systems (the mechanisms that change the mass and velocity of the vehicle), and
- launch platforms - ground, air, or sea-based.

ES.2 Potential Impacts of the Preferred Alternative

Various environmental criteria were used to determine the overall environmental impact associated with each alternative. The environmental impacts associated with the preferred alternative include three major categories, atmospheric, noise, and other environmental impacts. The atmospheric category includes an analysis of impacts to air quality, acid rain, ozone depletion, and global warming. The noise category includes an analysis of launch, in-flight and reentry noise on various human and animal receptors. The final category specifically addressed other environmental effects, includes an analysis of impacts to water, land, and biota, as well as analyzing socioeconomic, historical, cultural, and archaeological considerations. Specifically, potential impacts in the atmosphere were examined in the troposphere (atmospheric layer extending from the Earth's surface to 10 kilometers), stratosphere (atmospheric layer extending from 10 to 50 kilometers), mesosphere (atmospheric layer extending from 50 kilometers to 80 kilometers), and ionosphere (atmospheric layer extending from 80 to 1,000 kilometers). Potential noise impacts from launches include the effects of acoustic energy on receptors (e.g., people, wildlife, and on structures). Socioeconomic and environmental justice effects of the preferred alternative were also considered.

Other environmental effects were analyzed based on generic localized environments. These effects included the climate and atmosphere of the launch site, land resources, water resources, and biological resources. The environmental characteristics of six different types of ecosystems representing various potential licensed launch locations throughout the U.S. were used to describe the range of potential impacts of licensed launches. A marine animals strike probability analysis was also conducted. The PEIS is *not* site-specific; any required site-specific environmental documentation would be developed as needed.

ES.2.1 Atmospheric Impacts of the Preferred Alternative

The atmospheric impacts of the preferred alternative would be addressed for all levels of the atmosphere. The primary potential impacts to the troposphere may result from the ground cloud, the cluster of emissions formed from the ignition of rocket motors and the resulting launch of the LV. Other potential impacts to the troposphere could result from accidents on the launch pad or during flight. In the stratosphere, LV emissions could potentially affect global warming (the greenhouse gas effect) and depletion of the stratospheric ozone layer. In this analysis, no impacts are predicted to the mesosphere during nominal launches because air emissions are not an issue in this region of the atmosphere. Regarding the ionosphere, some exhaust products from LVs generated during launch from Earth to space have been found to have a temporary effect on electron concentrations in the F layer of the ionosphere.

ES.2.2 Noise Impacts of the Preferred Alternative

The noise impact of the preferred alternative would also be considered, particularly the impact of sonic booms. A sonic boom is the noise created by a shock wave occurring when an aircraft is traveling overhead faster than the speed of sound. The three concerns regarding sonic booms' effects on humans are health, startle, and annoyance. This analysis found no health impacts from the preferred alternative. While annoyance data appear to be inconclusive, people may be more sensitive to sonic booms than previously thought. The types of interference and activities people are involved in affect annoyance, and a wide range in estimating percent annoyed is reported in the literature. However, preliminary data indicate that people perceive sonic booms as more intrusive than aircraft noise at comparable levels.

Birds are most sensitive to noises at far higher frequencies than those associated with LV launches. Birds may be startled by impulsive noises created by LV launches, but this effect would most probably be of short duration. Mammals seem to be less disturbed by noise than birds, but startle effects can occur. Sonic booms from LV launches also impact underwater environments. These types of booms represent a threat of physical and physiological impairment to marine animals in the vicinity of the water surface, particularly if these animals are in the relatively restricted impact zone of the boom.

Structural damage may occur as a result of overpressure caused by the preferred alternative. Overpressure is a transient pressure, that occurs as a result of an explosion, that exerts a force that exceeds the standard atmospheric pressure. Damage to glass, plaster, roofs, and ceilings at exposed buildings might result. In well-built and maintained buildings, glass would receive the primary damage. Approximately one in 10,000 panes may be broken at an overpressure of four pounds per square foot (psf). LVs can possibly produce an overpressure in the two to three psf range.

ES.2.3 Local Impacts of the Preferred Alternative

Atmosphere. Characteristics of the local atmosphere substantially affect the air quality impacts of launches. These characteristics include wind speed and direction, temperature, humidity and rainfall, atmospheric stability and mixing heights (i.e., the altitude of the boundary layer or an inversion layer), and the topography of the area. The wind speed may affect the area over which the ground cloud may be dispersed. The hydrogen chloride (HCl) emissions from solid rocket motors react with moisture in the air and are rained out, thereby reducing the HCl load in all layers of the Earth's atmosphere. The mixing area is the atmospheric region where pollutants and emissions tend to remain. Atmospheric stability would also affect the impacts of LV launches. The more stable the atmosphere, the longer the ground cloud may hang over a particular area without much dispersion.

Land and Water. The environmental impacts to local land resources from the preferred alternative are mainly limited to impacts to soil from the formation of a launch ground cloud (from solid rocket motors) that produces acidic deposition. Soil impacts include temporary increases in available metals and temporary decreases in pH. Surface water impacts include temporary increases in available metals and temporary decreases in pH.

Biological Resources. Chronic impacts could result from subtle alterations in habitat and potentials for bioaccumulation (a progressive increase of the bodily content of a toxic compound) of pollutants that may be released into the environment from LV-related activities. Impacts to biological resources from repeated LV deposition close to the source can include fish kills and occasional mortality of terrestrial fauna. Flora in the vicinity of the launch site may be affected by the launch exhaust products or from combustion products associated with catastrophic events. Vegetation changes from repeated deposition close to the source include loss of sensitive species, decline in shrub cover, and increasing bare ground.

Launches also present a potential for acute impacts to fish and wildlife in the vicinity of the launch pad resulting from noise, blast debris, heat, and toxic chemicals. The possibility of acute noise impacts would depend on the size and type of LVs being launched. In general, the potential for impacts on biological resources from LV heat exhaust is limited by the use of appropriate mitigation measures such as berms or shields. The toxic chemical of primary concern is HCl associated with the use of solid propellants.

Regarding debris, there is a remote possibility that jettisoned or separated motors, stages or fairings from an ELV when they enter the ocean during nominal flight operations could strike a marine animal. According to the marine animal strike probability analysis conducted for this PEIS, less than 0.5 strikes are expected per year, even when all launch activity is summed, and a summation is done across all species over both the Atlantic and Pacific Oceans.

ES.2.4 Socioeconomic Impacts of the Preferred Alternative

Development and growth of the commercial launch industry would have a beneficial economic impact. Jobs associated with the commercial launch industry tend to be technology-based and require highly skilled workers with specialized skills and education.

ES.2.5 Environmental Justice Impacts of the Preferred Alternative

Because this is a programmatic EIS, analysis of environmental justice effects of the preferred alternative must be general and not site-specific in nature. Thus, environmental justice effects within the scope of this analysis are related to the socioeconomic effects. Because this analysis assumes that the preferred alternative would result in *positive* socioeconomic effects, including maintaining or increasing current employment levels in the U.S. launch industry, it is assumed that these positive effects would at a minimum not produce disproportionate *negative* impacts on minority or low-income populations.

ES.3 Potential Impacts of the More Environmentally-Friendly Propellant Combinations Alternative

Potential environmental impacts associated with the more environmentally-friendly propellant combinations alternative were analyzed in three major categories: atmospheric impacts, noise impacts, and other environmental effects. Specifically, potential impacts in the atmosphere were examined in the troposphere, stratosphere, mesosphere, and ionosphere. Potential noise impacts of launch activities on receptors were analyzed for human beings, wildlife, and structures. Socioeconomic and environmental justice effects of this alternative were also considered.

This alternative is defined as preferentially licensing those vehicles that are not solely propelled by solid rocket motors (SRMs). This would reduce the total number of U.S. licensed launches projected from 2000 through 2010 from 261to 189. The number of launches using liquid, liquid/solid, or hybrid propellant systems was assumed to remain unchanged under this alternative. Thus, the total number of

FAA-licensed launches in the U.S. (i.e., programmatic launches) would decrease substantially under this alternative. It was assumed that the decrease in U.S. licensed launches that use only solid propellants would be compensated for by an increase in these launches elsewhere in the world.

ES.3.1 Atmospheric Impacts of the More Environmentally-Friendly Propellant Combinations Alternative

Potential impacts in the atmosphere from this alternative were examined in the troposphere and stratosphere. No change was estimated relative to the preferred alternative for effects in the mesosphere and ionosphere. It is important to note that conclusive data and analysis regarding the specific impacts of emissions from multi-propellant propulsion systems (e.g., liquid and solid combinations) currently do not exist. Because the environmental impacts related to combined emissions of multi-propellant systems have not been adequately characterized at this time, this analysis relies on existing, available data on emissions from single propellant systems. Ongoing U.S. Air Force and industry research in this area may alter the future understanding of the cumulative atmospheric impacts of multi-propellant propulsion systems and the relative atmospheric impacts of these different types of systems.

The specific HCl input to the stratosphere from launch vehicle exhaust can be estimated if the HCl amount and its time-dependent releases along the ascent are known. Using the number of launches estimated in Section 2.0, but eliminating all launches using solely solid propellant systems in the troposphere and stratosphere, the emission load of HCl in the stratosphere for all U.S. licensed launches from 2000 through 2010 (a period of 11 years) is approximately 1,787 tons, and additional free Cl load is 24 tons. This averages to approximately 165 tons of HCl and Cl load to the stratosphere from U.S. licensed launches per year. (See Appendix A, Emission/Afterburning Products and Loads for a detailed methodology determining numbers and emissions loads.) In comparison, under the preferred alternative, the emission load of HCl in the stratosphere for all U.S. licensed launches from –2000-2010 is approximately 2,292 tons, and additional free Cl load is 31 tons. This averages to approximately 211 tons of HCl and Cl load to the stratosphere from U.S. licensed launches per year. Overall, emissions of concern resulting from potential accidents on the launch pad and from activation of flight termination systems would also be reduced under this more environmentally-friendly propellant alternative, because launch vehicles using only solid propellant systems would no longer be licensed and launched in the U.S. or by companies requiring U.S. licenses for launches abroad. However, this reduction in emissions from avoided accidents was not quantified in this analysis.

ES.3.2 Noise Impacts of the More Environmentally-Friendly Propellant Combinations Alternative

This alternative is anticipated to have fewer noise impacts than the minimal impacts associated with the preferred alternative.

ES.3.3 Local Impacts of the More Environmentally-Friendly Propellant Combinations Alternative

The more environmentally-friendly propellant combinations alternative would reduce the impact of licensed launches on soils in the vicinity of launch pads. Space Shuttle and other government launches would still have an impact on soil pH, but the cumulative effects from these launches, as a result of fewer licensed launches involving only solid propellant, would not be as great. The prospect of additional local water impacts near a commercial launch site from licensed launches would also be reduced. Additionally, coastal waters that could be affected in the event of an accident would experience reduced impacts.

Vegetation changes from the ground cloud at launch, as well as wildlife impacts from launch activities, would be reduced. However, the demand for launches could lead to construction of launch sites outside the U.S. These launch sites could potentially have a significant impact on biodiversity if they are sited on or near endangered or biologically fragile ecosystems (i.e., rain forest, habitats of endangered species). The probability of jettisoned ELV sections (e.g., spent stages, payload fairings) making direct contact with a marine species would remain remote under this alternative.

ES.3.4 Socioeconomic Impacts of the More Environmentally-Friendly Propellant Combinations Alternative

Development and growth of the commercial launch industry would have a beneficial economic impact; limiting this development and growth by preferentially licensing a subset of LVs would reduce the magnitude of this beneficial impact relative to the preferred alternative.

ES.3.5 Environmental Justice Impacts of the More Environmentally-Friendly Propellant Combinations Alternative

Because this is a programmatic EIS, analysis of environmental justice effects of this alternative must be general and not site-specific in nature. Thus, environmental justice effects within the scope of this analysis are related to the socioeconomic effects. Because this analysis assumes that this alternative would result in *positive* socioeconomic effects (although less relative to the preferred alternative), including maintaining or increasing current employment levels in the U.S. launch industry, it is assumed that these positive effects would at a minimum not produce disproportionate *negative* impacts on minority racial, ethnic, or economically-disadvantaged populations.

ES.4 Potential Impacts of the No Action Alternative

Because 49 U.S.C. Subtitle IX, ch. 701 -- Commercial Space Launch Activities, formerly the Commercial Space Launch Act (CSLA), requires launches by U.S. entities to be licensed, the U.S. launch industry would be unable to continue LV launch operations regardless of their location under the no action alternative. Chapter 701 requires the FAA to license a launch if the applicant complies and will continue to comply with chapter 701 and implementing regulations. 49 U.S.C. § 70105. One of the purposes of chapter 701 is to provide that the Secretary of Transportation, and therefore the FAA, pursuant to delegations, oversees and coordinates the conduct of launch and reentry, and issues and transfers licenses authorizing those activities. 49 U.S.C. § 70104 (b) (3). The agency has the authority to prevent a launch if it decides that the launch would jeopardize public health and safety, safety of property, or national security or a foreign policy interest of the United States. 49 U.S.C. § 70104 (c). Not licensing any U.S. launches would not be consistent with chapter 701 in this context. Additionally, the no action alternative could negatively impact the national security and foreign policy interests of the United States. Some U.S. government payloads have been launched by the U.S. commercial launch industry. Therefore, if access to vehicles used for licensed launches is not available, this overall limit in available capacity could, in a worst case scenario, impact the U.S. government's ability to launch needed payloads and negatively affect programs that rely on access to space. Additionally, parties that had planned to launch from U.S. launch sites would be forced to find alternatives, potentially exposing sensitive technologies to countries with competing economic and security interests.

Under the no action alternative, it was assumed that the same number of worldwide launches would take place. However, because the FAA would cease issuing licenses for launches in the United States, the launches would take place from foreign locations. In the absence of access to licensed launches in the United States, it is likely that other countries with existing launch programs (e.g., France, Russia, China, Canada) would significantly expand their programs to accommodate the demand. In addition, it is even possible that countries currently without existing launch programs would initiate launching of vehicles used for commercial operations to meet this demand.

ES.4.1 Atmospheric Impacts of the No Action Alternative

It is possible that if no LV launches could take place from the U.S. that fewer LVs would be launched overall worldwide unless existing foreign launch programs could expand rapidly to accommodate increased launch requirements. This would result in an overall decrease globally in LV emissions potentially affecting the atmosphere. However, based on the comparison of capacity and propulsion systems, the transfer of launches from U.S. LVs to foreign LVs (e.g., Zenit, Proton, Ariane IV and V, Long March, H2, GSLV, PSLV, and M-V) could cause an increase in atmospheric emissions overall (this analysis is described in detail in Appendix A of this PEIS). Any specific effects that might be associated with launches such as the potential for acid rain, and highly transient and localized stratospheric ozone depletion, would occur outside the U.S. However, the potential for global warming and stratospheric ozone depletion would remain essentially the same based on the assumption that an equal number of launches would occur in either case.

ES.4.2 Other Impacts of the No Action Alternative

The prospect of noise impacts and sonic booms near U.S. launch sites would be eliminated. If no licensed launches occurred, there would be no impact on the soils in the vicinity of launch pads at U.S. launch sites. Space Shuttle and other government launches would still have an impact on soil pH, but the cumulative effects from these launches, absent the licensed launches, would not be as great. The prospect of local water impacts near the launch site would be eliminated. Additionally, coastal waters that could be affected in the event of an accident would no longer be potentially impacted.

Vegetation changes from the ground cloud at launch would be eliminated, as well as wildlife impacts from launch activities. The probability of jettisoned ELV sections (e.g., spent stages, payload fairings) making direct contact with a marine species would remain remote. However, the increased demand for satellite launches could lead to construction of launch sites outside the U.S.[1] These launch sites could potentially have an impact on the world wide biodiversity if they were sited on or near endangered or biologically fragile ecosystems (i.e., rainforest or habitats of endangered species).

ES.4.3 Socioeconomic Effects of the No Action Alternative

The no action alternative would have negative socioeconomic impacts by forcing all payloads currently planned for launch in the U.S. to use foreign launch vehicles. As a result, U.S. jobs would be lost to foreign entities to support their launch activities and programs. It is possible that U.S. telecommunications companies and other U.S. launch users would be given lower priority in launching satellites, creating a potential for scheduling problems and loss of competitiveness in the global technology market.

The U.S. economy would not enjoy the full potential benefits of high-technology jobs or multi-billion dollar revenues derived from the commercial launch industry. Companies directly involved in providing launch services would no longer be able to operate in that capacity and would be significantly affected. Companies that produce launch vehicle engines or vehicle components could also experience a decline in revenue. The impact to hardware producers would be less severe than for service providers because: (1) the revenue stream from continued military launches would likely continue; and (2) the opportunity for sales of propulsion units and vehicle components overseas could improve because foreign launch providers would need more vehicles to meet the demand from the increase in U.S. payloads seeking their launch services.

Closing the licensed launch industry to the U.S. private sector would both foreclose potential domestic economic benefits and reduce U.S. international competitiveness. If technological advances are achieved during the development and use of foreign LVs, foreign enterprises would gain further advantages in marketing these new goods and services. Thus, foreign economies could possibly be stimulated, while the U.S. would lag behind, both economically and technologically in this market.

ES.4.4 Environmental Justice Effects of the No Action Alternative

Because the no action alternative would have negative socioeconomic impacts that may result in a loss of U.S. jobs to foreign entities, it is possible that minority or low-income populations may suffer some disproportionate affects of these job losses.

ES.5 Potential Cumulative Impacts

Cumulative impacts are defined as the impacts on the environment which result from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. 40 CFR § 1508.7. Only the cumulative atmospheric impacts of licensed launches combined with all other vehicle launches worldwide were analyzed. Other cumulative impacts, including most cumulative noise and local environmental impacts, would be site-specific and are beyond the scope of this PEIS. These cumulative impacts would be considered in site-specific documentation.

This PEIS examines impacts and cumulative impacts from "programmatic" launches, i.e., launches requiring licenses from the FAA. All other vehicle launches, or "non-programmatic launches," consist of U.S. government launches, foreign commercial launches, and foreign government launches. The potential for cumulative impacts from programmatic LV activity is assessed through a comparison to launch activity worldwide (i.e., programmatic and non-programmatic launches). The conclusion of many studies previously done on the cumulative environmental effects of launch vehicle launches worldwide is that the effects of LV propulsion on stratospheric ozone depletion, acid rain, toxicity, air quality, and global warming are extremely small compared to other industrial or man made impacts. This corresponds to the conclusions of this PEIS.

ES.5.1 Cumulative Atmospheric Impacts

The cumulative impact of all of tropospheric emissions loadings from launches is relatively insignificant compared with industrial and natural emissions loadings to the troposphere.

Furthermore, the cumulative impacts of LV launches on global warming and depletion of the stratospheric ozone layer are insignificant compared to other global industrial sources. Even when accounting for both programmatic and non-programmatic (cumulative impact) carbon monoxide/carbon dioxide (CO/CO_2) loads combined, the cumulative impact of the preferred alternative on global warming is negligible compared to emissions loads from other industrial sources just in the United States. Similarly, the cumulative impact on stratospheric ozone depletion from launches is far below and indistinguishable from the effects caused by other natural and man-made causes. In general, ongoing analyses of LV exhausts indicate that the potential for ozone depletion associated with LV exhaust to cause an increase in solar ultraviolet (UV) intensity near launch sites is extremely limited.

This PEIS does not predict any cumulative impacts to the mesosphere or ionosphere. The more launch vehicles that are launched, the greater the potential for creating "holes" in the ionosphere; however, based on available data indicating that this effect is temporary, the cumulative impacts to the ionosphere are assumed to be minute.

When an accident occurs near the launch pad or a launch anomaly results in using in-flight termination capabilities (if equipped), there is a cumulative effect on air quality, potential global warming, and stratospheric ozone depletion. For accidents that occur in the stratosphere, HCl and nitrogen oxides (NO_x) emissions could potentially contribute to stratospheric ozone depletion, while CO_2 emissions could potentially contribute to global warming. These effects of an accident on ozone depletion and global warming would be greater with a larger capacity LV versus a smaller capacity LV. Although on a cumulative basis the likelihood of accidents occurring increases as the number of launches increases, accidents involving launch vehicles are relatively uncommon events primarily because launches of these vehicles are infrequent events especially as compared to other traditional modes of transportation. It should be noted that the FAA assumes a failure probability ranging from 10% to 31%, depending on the number of missions flown by a vehicle. Therefore, the overall cumulative impacts from accidents are insignificant as compared with other emission sources.

ES.5.2 Cumulative Noise Impacts

In general, the potential cumulative impacts of noise from LV launches are expected to be local effects that are expected to impact the area around the launch pad. However, an important possible cumulative noise impact might include changes in the migrating route and habitat choice of certain marine animals exposed to repeated occurrences of sonic booms from LVs. These sonic booms would occur in areas downrange of the launch pad.

ES.6 Irreversible And Irretrievable Commitment Of Resources

The launch of LVs requires the commitment of natural resources, including the consumption of mineral resources. No additional cultural resources, whether human or land resources, are expected to be committed to the launching of LVs beyond those that have been or will be addressed in site-specific NEPA documentation. Basic commitments of natural and cultural resources for licensed launches are not different from those necessary for many other research and development programs; they are similar to the activities that have been carried out in previous space program activities over the past 25 years.

ES.7 Mitigation Actions

A variety of mitigation measures are recommended for consideration to prevent or reduce environmental effects associated with the preferred alternative. Monitoring is needed at individual launch sites, such as water sampling and analyses, cultural and archeological surveys of areas with historical artifacts, and biological species surveys by specialists to monitor the health and numbers of biological species of concern. In addition, it is assumed that all launch sites would comply with permit conditions imposed by regulatory authorities, which represent a substantial mitigation action. Other examples of suggested mitigation measures include: (1) appropriate noise control actions, including blast fences, berms, and launch timing/seasonal restrictions, as needed; (2) promoting the use of environmentally-friendly propellants, as feasible; (3) engaging in voluntary waste pollution prevention programs; (4) developing a comprehensive environmental management system; (5) working with stakeholders to avoid conducting launches in culturally or archeologically-sensitive areas to the maximum extent possible; and (6) implementing effective lighting policies to protect wildlife. Mitigation measures are discussed in further detail in Section 9 of this PEIS. This section examines possible mitigation measures for noise and solid and hazardous waste. This section also addresses ways to minimize adverse impacts to water quality, air quality, cultural and historical resources, and biological resources.

1. INTRODUCTION

1.1. Preferred Alternative

In recent years, the private sector has expressed heightened interest in launching vehicles, projects that have previously been conducted only by the federal government. According to 49 U.S.C. Subtitle IX, ch. 701 -- Commercial Space Launch Activities, the development of vehicles used for launches and associated services is in the national and economic interest of the United States. To ensure that launch services provided by private enterprises are consistent with national security and foreign policy interests of the U.S., and do not jeopardize public safety and the safety of property, the Department of Transportation (DOT), Federal Aviation Administration (FAA), is authorized to regulate and license U.S. launch activities. Within DOT and the FAA, the Secretary's authority has been delegated to the office of the Associate Administrator for Commercial Space Transportation (AST). This authority extends to licensing launches and is considered to be a major federal action subject to the requirements of the National Environmental Policy Act (NEPA) of 1969, as amended, 42 U.S.C. § 4321, et seq.

1.2. Purpose and Need of Preferred Alternative

Launch licenses are needed to provide a mechanism for ensuring protection of public health and safety. U.S. laws and policy and international treaties recognize the technological and economic importance of developing space transportation. They also identify the requirement for the proper oversight and control of launches. Specifically, 49 U.S.C. ch. 701 encourages the development of a commercial launch industry, and authorizes the Secretary of Transportation to oversee, license, and regulate launches and to issue and transfer launch licenses. The Secretary is charged with the responsibility to protect public health and safety, the safety of property, and national and foreign policy interests of the U.S. Thus, the FAA's launch review and licensing procedures are necessary to ensure that launch applicants meet conditions designed to protect the public health and safety, safety of property, and national security and foreign policy interests. These conditions include:

- adhering to launch safety regulations and procedures,
- complying with requirements concerning pre-launch record keeping and notifications, including those pertaining to federal airspace restrictions and military tracking operations,
- complying with federal inspection, verification, and enforcement requirements , and
- securing the minimum amount of third-party liability insurance specified by DOT.

1.3. Environmental Responsibility of the FAA

Under the authority of the 49 U.S.C. Subtitle IX, ch. 701, the FAA determines whether to issue a launch license. Issuing a launch license is considered a major federal action and is subject to review as required by NEPA. This Programmatic Environmental Impact Statement (PEIS) evaluates the potential environmental consequences of licensed launches. In February 1986, the FAA published a Programmatic Environmental Assessment (EA) of Commercial Expendable Launch Vehicle Programs. The Programmatic EA addressed the programmatic aspects of licensed launches and has been used for environmental review of launch applications to date. This PEIS updates and replaces the existing EA.

This PEIS addresses the potential environmental impacts of licensing the launch of launch vehicles (LVs). It will be used by the FAA, in conjunction with other documentation, to assess the environmental impacts of licensed launches and to support licensing of such launches. The FAA may find it necessary to require a launch license applicant to submit additional information to supplement this PEIS. Additional environmental documentation may be needed by the FAA in its licensing decisions, and that could include site-specific launch site environmental analyses and mission-specific information. Information such as the actual design of the launch vehicle and any payload, system testing and evaluation records, maintenance records, launch site range safety plans and procedures, emergency and countermeasures plans, critical failure mode and effects analyses, and mission-specific objectives will be reviewed and evaluated by the FAA as a part of the licensing process. In addition, the launch proponent would be responsible for complying with all applicable Federal, state, and local laws and regulations and international treaties. License applicants are required to comply with all applicable waste disposal regulations including Resource Conservation and Recovery Act (RCRA) requirements. Relevant Federal, state, and local laws and regulations and international treaties are discussed elsewhere in the document and appendices.

1.4. Scope of this PEIS

This PEIS considers, at the programmatic level, the environmental impacts of licensing launches. This PEIS analyzes in detail the potential environmental impacts of the estimated 261 licensed launches that would result from the proposed licensing program. Included in the analysis are potential environmental impacts resulting from ignition and lift-off to payload separation and the deposition of LV components downrange. Site-specific, localized environmental effects would be subject to an individual review. For the purpose of this document, LVs are launch vehicles with the ability to operate in, or place payloads in, outer space. Launch Vehicles (LVs) in this PEIS are comprised of both expendable launch vehicles (ELVs) that have stages or components that are not intended for recovery or reuse, and reusable launch vehicles (RLVs) that have stages or components that can return to Earth and be recovered and reused.[c] LVs do not include "amateur rocket activities" conducted at private sites[d]. LVs are used to transport government, scientific, and commercial payloads (e.g., communication satellites, other vehicles, scientific experiments) from Earth into various orbits around Earth, including Low Earth Orbit (LEO), elliptical orbit, and geosynchronous transfer orbit (GTO), as well as to the moon and other bodies in this solar system. Sounding rockets, used to lift payloads to altitudes as high as 1,500 km, are also included in this PEIS.

Objects in LEO follow a path between the Earth's atmosphere and the bottom of the Van Allen belts, from an altitude of 100 to 1,000 miles. The Van Allen belts are zones of intense radiation trapped in the Earth's magnetosphere. The magnetosphere is a region dominated by the Earth's magnetic field that traps charged particles. The magnetosphere begins in the upper atmosphere, where it overlaps the ionosphere, and extends several thousand miles further into space. Geosynchronous transfer orbit is an orbit that originates with a parking orbit (i.e., a flight path in which vehicles go into LEO, circle the globe in a waiting posture and then transfer payloads to final higher orbits) and then reaches apogee (i.e., the point in an orbit that is furthest from the Earth) at Geosynchronous Earth Orbit (GEO). GEO is an orbit at 22,300 miles altitude that is synchronized with the Earth's rotation. If a satellite in geosynchronous orbit is not at 0 degrees inclination, its ground path describes a figure eight as it travels around the Earth.

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[c] Reentry vehicle means a vehicle designed to return from earth orbit or outer space to Earth, or a reusable launch vehicle designed to return from earth orbit or outer space to Earth, substantially intact. 49 U.S.C. § 70101 (13). Reentry vehicles were previously considered in the Final Programmatic Environmental Impact Statement for Commercial Reentry Vehicles (1992).

[d] "Amateur rocket activities" are defined in 14 Code of Federal Regulations (CFR) 401.5 as "launch activities conducted at private sites involving rockets powered by a motor or motors having a total impulse of 200,000 pound-seconds or less and a total burning or operating time of less than 15 seconds, and a rocket having a ballistic coefficient-i.e., gross weight in pounds divided by frontal area of rocket vehicle--less than 12 pounds per square inch."

This PEIS includes licensed launches from existing government launch facilities, licensed launches from launch sites developed at or near government launch facilities, and licensed launches from launch sites that would require new development and construction. Potential environmental effects of launches from ignition, liftoff and ascent through the atmosphere to orbit, and the disposition of launch vehicle components down range are assessed. The PEIS scope encompasses all activities from lift-off to payload separation. Related activities, including vehicle assembly and payload preparation prior to liftoff, payload functioning during useful life, and payload reentry whether controlled or uncontrolled, are outside the scope of this PEIS. Because the scope is limited to assessment of environmental consequences of launches, no construction activities (e.g., development of new launch sites) are assessed. Construction activities, if they occur, would be addressed in separate site-specific environmental documentation.

The scope of this PEIS does not include site-specific, localized effects. Localized effects and the cumulative impact of these localized effects at an individual launch site can only be appropriately analyzed in the environmental review of a launch site operator. Environmental reviews in support of launch licenses address the environmental impacts associated with issuing a license. Environmental reviews in support of launch operator licenses address the local and cumulative impact of launches from the specific site. Both types of reviews (i.e., launch licenses and launch operator licenses) are expected to tier from this PEIS.

The FAA has prepared a separate PEIS (Programmatic Environmental Impact Statement for Commercial Reentry Vehicles, May 1992) to assess the impacts of licensing reentry vehicles (RVs). The RV PEIS includes impacts from atmospheric emissions, noise sources, and landing activities. In the future, technologies may be developed by industry and incorporated into LVs that are licensed by the FAA that combine characteristics of expendable launch vehicles and reusable launch vehicles. Programmatic consideration of the reentry phase for reusable components was included in the May 1992 RV PEIS; consideration of the launch phases, including noise and atmospheric effects, is included in this assessment. Site-specific documentation would address general ground operations and site-specific safety and other environmental issues.

As the designated authority for regulating U.S. launch activity and the responsible agency for issuing launch licenses, the FAA is the lead agency for preparation of this PEIS. Consultation with other federal and state agencies was initiated through the scoping process. No other agency has been designated a cooperating or co-lead agency.

1.5. Roadmap to the PEIS

Section 2.0 provides a description of the preferred alternative, the more environmentally-friendly propellant combinations alternative, and the no-action alternative. Section 3.0 describes the existing environment potentially impacted by launch operations. Section 4.0 describes potential accident scenarios. Section 5.0 describes the potential environmental impacts and consequences of the preferred alternative. Section 6.0 describes the potential environmental impacts and consequences of the more environmentally-friendly propellant combinations alternative. Section 7.0 describes the potential environmental impacts and consequences of the no action alternative. Section 8.0 describes the potential cumulative impacts of the preferred alternative. Section 9.0 discusses mitigation of the potential environmental impacts of the preferred alternative. Section 10.0 outlines the relationship between short-term use and the long-term effects of the preferred alternative on the environment. The commitment of resources for licensed launch programs is discussed in Section 11.0. Section 12.0 provides a description of the public coordination process, and coordination comments received during scoping.

The preparers of the PEIS are listed in Section 13.0. A glossary of terms used in this document is included after Section 13.0. Several appendices provide technical support for impact analyses, regulatory background, and the distribution list for the PEIS.

2. ALTERNATIVES

2.1. Introduction

The commercial launch industry has attempted to promote convenient, affordable access to space, to satisfy the payload lift requirements of its customers, and to promote commercial development of space. In the past three decades, space has become increasingly important in a broad range of areas including scientific research, communications, and navigation. Technologies such as telecommunications and microgravity crystal growth are making use of space and its unique environment and are being developed for direct application in commercial use. These new technologies, and industry's desire to market them, have created the need for increased launch transportation. The demand for access to space cannot be met by the current or foreseeable U.S. military or National Aeronautics and Space Administration (NASA) launch vehicles, and so the commercial launch industry is critical to ensure the U.S. remains in the forefront of space development. Furthermore, current U.S. space policy requires that the U.S. government encourage private sector and state and local government investment and participation in the development and improvement of U.S. launch systems and infrastructure.[2]

The primary commercial use for launches is placement of communication satellites in either LEO or GTO. The demand for communication satellites has been steadily growing due to new technologies such as mobile communications services and global positioning systems, as well as direct broadcast systems and remote sensing satellites. Demand for communication satellites arises from U.S.-based companies and foreign initiatives (which can be government or privately sponsored). Although communication satellites are the most frequent payloads at this time, other commercial applications are possible in the future. Sounding rockets carry payloads to an altitude of 1,500 km with recovery of payload possible, and are used to support scientific experiments.

2.2. Preferred Alternative

2.2.1. Description of Action

The preferred alternative for this PEIS is the Launch Licensing Alternative. The categories of LVs under consideration for analysis of environmental impacts under this preferred alternative would encompass the following LV characteristics and launch profiles:

- payload capacity,
- types of propulsion systems, and
- launch platforms -- ground, air, or sea-based.

As detailed above in Section 1.4, launches from government and commercial launch sites are included in the preferred alternative. This PEIS considers the effects of licensed launches from ignition, liftoff and ascent through the atmosphere to orbit, to payload separation. During ascent through the atmosphere, expended stages and other hardware (e.g., fairings) are jettisoned, usually into oceans; this activity is within this PEIS's scope. In contrast, reusable stages could be returned to Earth via parachute for recovery; impacts of such reentry activities are assessed in the FAA's 1992 PEIS for Commercial Reentry Vehicles. The remaining events of a launch (e.g., vehicle assembly, payload preparation, payload functioning during useful life, and payload reentry, if applicable) are not addressed by this PEIS.

LVs can place payloads in various orbits around Earth, including LEO elliptical orbits, and geosynchronous transfer orbits. Generally, if a payload is to be placed in GTO it requires an LV with multiple propulsion stages. The orbit in which an LV places its payload depends upon the LV's trajectory (the curve described by an object moving through space), launch location, and payload capacity. Sounding rockets do not place a payload in orbit, but instead return to Earth after a rapid ascent. Total flight time of up to about 20 minutes allows for conducting scientific experiments.

2.2.2. Licensed Launch Estimates

The FAA estimates that the total commercial worldwide launch demand to place payloads in LEO and GTO orbits between 2000-2010 would require 650 launches.[e] As seen in Table 2-1, the total number of U.S. GTO and LEO launches estimated for all types of currently proposed vehicles for this analysis is 261. The criteria under which the FAA would grant licenses are described in 49 U.S.C. Subtitle IX, ch. 701-- Commercial Space Launch Activities and supporting regulations. Although these numbers assume a larger U.S. market share than currently anticipated, the FAA is evaluating an upper bound in case of unforeseen events, such as international LV accidents or new technology requirements, that could dramatically increase the number of licensed LVs launched from the U.S.

TABLE 2-1
TOTAL NUMBER OF U.S. LICENSED LAUNCHES BY LAUNCH CAPACITY CATEGORY, 2000-2010

	# OF U.S. LAUNCHES
SMALL CAPACITY <2,000 lb GTO or < 5,000 lb LEO	72
MEDIUM CAPACITY 2,000-3,999 lb GTO	22
INTERMEDIATE CAPACITY 4,000-8,999 lb GTO or >5,000$^+$ lb LEO	75
HIGH CAPACITY 9,000-10,000$^+$ lb GTO	92
TOTAL	261

Note: LVs delivering multiple payloads to orbit are classified under their cumulative payload capacity.

Table 2-2 summarizes the distribution of small, medium, intermediate, and high capacity launches by year from 2000-2010. The total U.S. licensed launch estimates were based on internal FAA estimates considering the number of licensed launches from U.S. government facilities, launches to LEO, launches to GTO, and separate launch estimates for the Sea Launch vehicle. Using these numbers, the specific breakdown by capacity is described below.

[e] 2000 Commercial Space Transportation Forecasts, Associate Administrator for Commercial Space Transportation and COMSTAC, May 2000.

TABLE 2-2
TOTAL NUMBER OF SMALL CAPACITY U.S. LICENSED LAUNCHES BY CAPACITY FOR THE YEARS 2000-2010

Capacity	Number of U.S. Launches											
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total*
Small	4	4	6	8	9	6	7	6	7	6	9	72
Medium	2	2	2	2	1	1	4	3	2	1	2	22
Intermediate	6	6	6	8	7	7	8	7	7	6	7	75
High	6	7	8	9	9	9	9	8	9	9	9	92
Total												261

* Source: FAA estimates (June 2000).

Small Capacity Launch Estimates. U.S. small capacity launches are defined as launch vehicles capable of launching payloads of less than 2,000 lb to GTO or less than 5,000 lb to LEO. The launch estimates include small licensed launches to LEO (56 launches) from launch sites. It also includes small capacity licensed launches from U.S. government facilities (16 launches) based on the assumption that roughly 60% of all launches from U.S. government facilities were of small launch capacity. The remaining 40% of launches from U.S. government facilities were of an intermediate capacity.

Medium, Intermediate, and High Capacity Launch Estimates. The launch estimates for medium, intermediate, and high capacity U.S. licensed launches were based on FAA projections for LEO and GTO. The LEO estimates for U.S. licensed medium to heavy vehicles was 51. Based on figure 15 of the COMSTAC report, it was determined that of these 51 launches, approximately 50% of the vehicles were medium and about 50% were intermediate as defined.[3] None of the vehicles listed in figure 15 of the COMSTAC report were considered high capacity. The GTO estimates were broken down by intermediate and high capacity based on Table 4 of the COMSTAC report.[4] Again, approximately 50% of the GTO estimates were considered intermediate and the remaining 50% were considered high capacity. Additionally, for intermediate launches, 40% of the launches were presumed to originate from U.S. government sites. The high capacity launch estimates also included 52 launches of the Sea Launch vehicle between 2000 and 2010.

To summarize, the estimates for medium capacity (22 launches from the years 2000-2010) came from the 50% of the LEO estimates. The estimate for intermediate capacity (75 launches from the years 2000-2010) came from the 40% from U.S. government launch facilities (11 launches), the approximate 50% of the LEO estimates (29 launches), and the approximate 50% of the GTO estimates (35 launches). The estimate for high capacity (92 launches from the years 2000-2010) came from the approximate 50% of the GTO estimates (40 launches) and 52 Sea Launch estimates. Using the same assumptions and methodology, a similar effort was performed to breakdown worldwide commercial launch estimates into medium, intermediate, and high capacity based on COMSTAC estimates.[5]

2.2.3. Characterization of LV Activities

LV activities for this PEIS are categorized using three different criteria: payload capacity (i.e., small, medium, intermediate, and large), propellant type, and launch platform. Payload capacity refers to the mass an LV can lift into a particular orbit, such as LEO or GTO. Predicted number of launches by payload capacity is detailed in Table 2-4. Propellant types and launch platforms are discussed below.

Propulsion Systems. Existing LVs use one or a combination of more than one of the following propulsion systems: liquid hydrocarbon propellant (e.g., Rocket Propellant 1 (RP1) plus an oxidizer such as liquefied oxygen (LO_x)); cryogenic propellants (e.g., LO_x/liquefied hydrogen (LH_2) , where the fuel and oxidizer[f] are maintained at very low temperatures); hypergolic propellants (e.g., hydrazine or nitrogen tetroxide, where the mixing of the hydrazine fuel and the nitrogen tetroxide oxidizer ignites without an initiating energy source), and solid propellant (e.g., polybutadiene matrix acrylonitrile oxidizer and powdered aluminum). SRMs are used in many vehicles as a booster to supplement the first stage of a launch vehicle. Concentrated hydrogen peroxide has also been used in several launch systems and is proposed to be used in several new launch vehicles as both a monopropellant as well as in combination with kerosene or alcohol based fuels. Although concentrated hydrogen peroxide was used in early launch vehicles it has not been used in recent years in major launch systems. The Naval Air Warfare Weapons Division at China Lake, California has been working on developing a propellant system which would use 98% rocket grade hydrogen peroxide and alcohol based fuels which can produce ignitions delays similar to hypergolic reactions achieved with nitrogen tetroxide and monomethyl hydrazine.

LVs can have one or more stages. Generally, if a payload is to be placed in GTO, current technology requires an LV with multiple propulsion stages. Hybrid systems store propellants in two different states, solid and liquid. Hybrid systems most commonly consist of solid fuel and liquid oxidizer. They have the advantages of increased safety, versatility, and robustness, but may be less efficient in terms of combustion process than in purely liquid or solid systems.[6] Hybrid propulsion systems are currently under development and could be used for licensed launches in the future. The hybrid system currently being tested for flight consists of solid propellant with LO_x as a liquid oxidizer, giving this system the ability to throttle, shut-off, and restart in mid-flight.

[f] An oxidizer is a substance such as perchlorate, permanganate, peroxide, nitrate, oxide or the like that yields oxygen readily to support the combustion of organic matter, powdered metals, and other flammable material.

TABLE 2-4
U.S. LAUNCH SYSTEMS BY PAYLOAD CAPACITY AND PROPELLANT TYPE

	SOLID PROPELLANTS	LIQUID PROPELLANTS			HYBRID PROPELLANTS
		Liquid Hydrocarbon	Hypergolic	Cryogenic	
SMALL CAPACITY <2,000 lb GTO or <5,000 lb LEO	X	X			
MEDIUM CAPACITY 2,000-3,999 lb GTO	X	X	X		
INTERMEDIATE CAPACITY 4,000-8,999 lb GTO or 5,000+ lb LEO	X	X	X	X	Anticipated
HIGH CAPACITY 9,000-11,000+ lb GTO	X	X	X	X	Anticipated

"X": Propellant currently in use for launch vehicle stage(s).

NOTES: Some LVs with multiple stages use more than one propellant type.
This table does not include payload attitude control system (ACS) propellants.
Vehicles with the ability to reach GTO are classified in this table as GTO vehicles; these vehicles may also be used to reach LEO.

Launch Platforms. LVs can be launched from land, air or sea-based launch platforms. Historically, almost all licensed launches have been from a land-based platform; however new LV designs are expanding licensed launch capability to air and sea. The advantages of launching from an air-or sea-based platform when compared to a fixed land-based platform include: reduced waiting time for a launch slot, ability to place payloads in equatorial or other orbits without the use of a larger LV, minimizing land overflight, minimizing environmental impacts, and possible cost savings. Table 2-5 summarizes current and proposed U.S. launch platforms.

TABLE 2-5
CURRENT U.S. LAUNCH SYSTEMS BY PAYLOAD CAPACITY AND LAUNCH PLATFORM

	LAND	AIR	SEA
SMALL CAPACITY <2,000 lb GTO or < 5,000 lb LEO			
MEDIUM CAPACITY 2,000-3,999 lb GTO			
INTERMEDIATE CAPACITY 4,000-8,999 lb GTO or >5,000+ lb LEO			
HIGH CAPACITY 9,000-10,000+ lb GTO			

Existing vehicles

No Industry Proposals at this Time

Small Payload Capacity. For this PEIS, a small payload capacity LV is a vehicle that can launch 2,000 pounds or less into GTO or 5,000 pounds or less into LEO. Most of these LVs are propelled by SRM boosters and can be launched from the ground or the air. The 1997 FAA launch manifest states that 25 percent of small capacity launches were launched from the air. It is probable that the percentage of air platform launches would be 50 percent or higher from 2000-2010. It is expected that approximately 72 small U.S. licensed launches would occur between 2000-2010. Figures 2-1 and 2-2 illustrate a typical flight sequence for air (Figure 2-1) and land-based (Figure 2-2) launches of vehicles carrying small payloads.

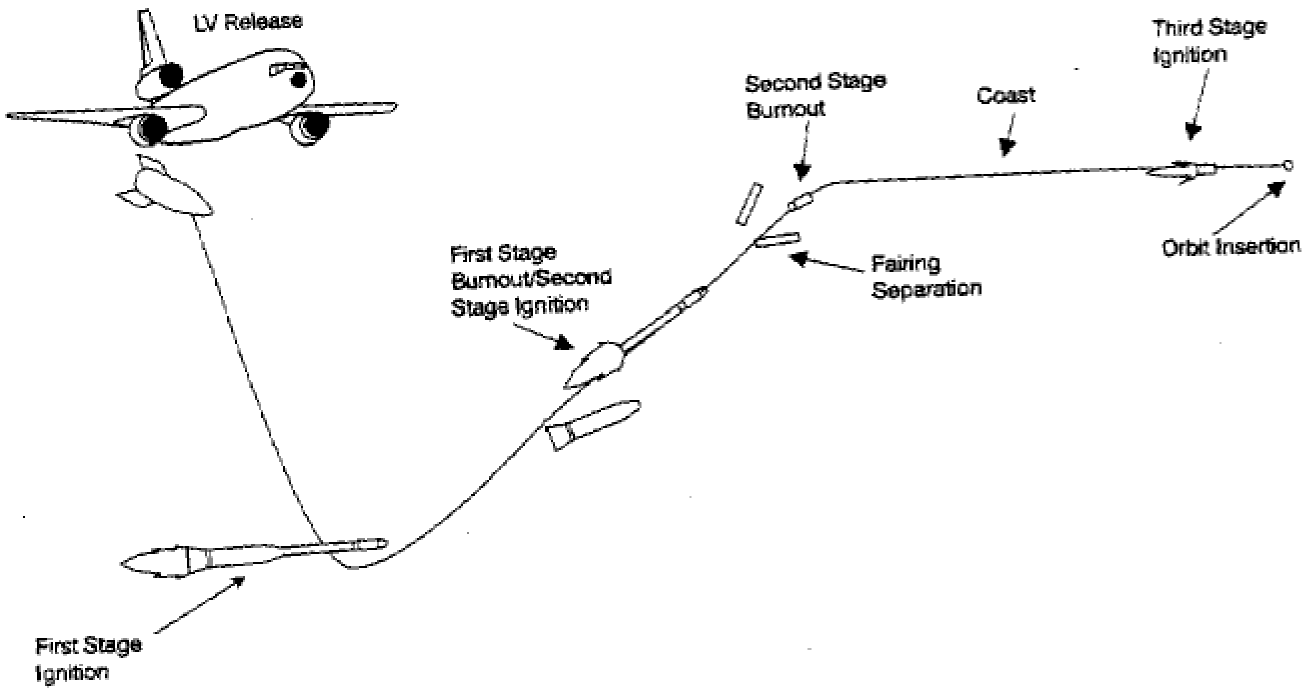
Medium Payload Capacity. An LV with medium payload capacity can put a 2,000 to 4,000 pound payload into GTO. Currently all LVs with this capacity launch from the ground, however it is conceivable that sea- or air-based launches could occur. For the purposes of the PEIS, it is estimated that 22 medium capacity LVs would be launched between 2000-2010. Most of the current medium LVs have at least two stages, one solid propellant and the other liquid propellant.

Although there are no hybrids known to be currently under development for this lift capacity. Figure 2-4 illustrates a typical flight profile for a medium or intermediate capacity LV. A hybrid propulsion system would consist of a solid propellant (powdered aluminum in a polymer matrix) with a liquid cryogenic oxidizer (liquid oxygen). Thus, hybrid LVs would be expected to emit alumina, but not HCl.

Intermediate Payload Capacity. The majority of licensed launches would be LVs with intermediate payload capacity. For the purposes of this PEIS, intermediate LVs are vehicles capable of carrying between 4,000 and 9,000 pounds into GTO or more than 5,000 pounds into LEO. Most intermediate capacity LVs are multi-staged with two liquid stages, or strap-on solids and liquid stages. Multi-staged LVs have two or more launch vehicle units each of which fires after the one before it exhausts its propellant. In the next three to five years, it is likely that there would be an intermediate capacity LV with a hybrid propulsion system. Currently all of the intermediate capacity LVs are launched from the ground. No documented plans have been identified to develop intermediate payload launch capacity from the air or sea. However, reusable vehicles with intermediate payload capacity are under development; one such vehicle would consist of two stages, using kerosene and LO_x. After a parachute- and air bag-assisted landing, the stages would be reassembled, re-fueled, and reused. This PEIS projects 75 intermediate category launches from 2000-2010. The flight profile in Figure 2-4 also applies for a typical intermediate capacity LV. The jettison of reusable vehicle stages is indicated with a dotted line as an optional approach.

High Payload Capacity. LVs with high payload capacity can lift from 9,000 to 10,000 lb into GTO. For the purpose of this PEIS, the high capacity category would also include future vehicles that have greater than 10,000 pounds payload capacity. It is likely that a hybrid propulsion system would boost the lift capacity of intermediate and high capacity LVs well past the 10,000 pound payload lift capacity threshold in the next 10 years. High capacity LVs have multiple stages including liquid and solid propulsion systems. The majority is launched from the ground, but future launches could be sea-based. A sea-based launch platform for high capacity vehicles has been developed. It is estimated that between 2000-2010 that over 25 percent of the high capacity launches would be from sea-based launch platforms. At this time it is not technically feasible to launch high capacity LVs from the air due to their size, propellant weight, and safety considerations. For the PEIS, the expected number of high capacity licensed launches between 2000-2010 is 92. For the high payload capacity LV, Figure 2-5 presents a typical flight profile.

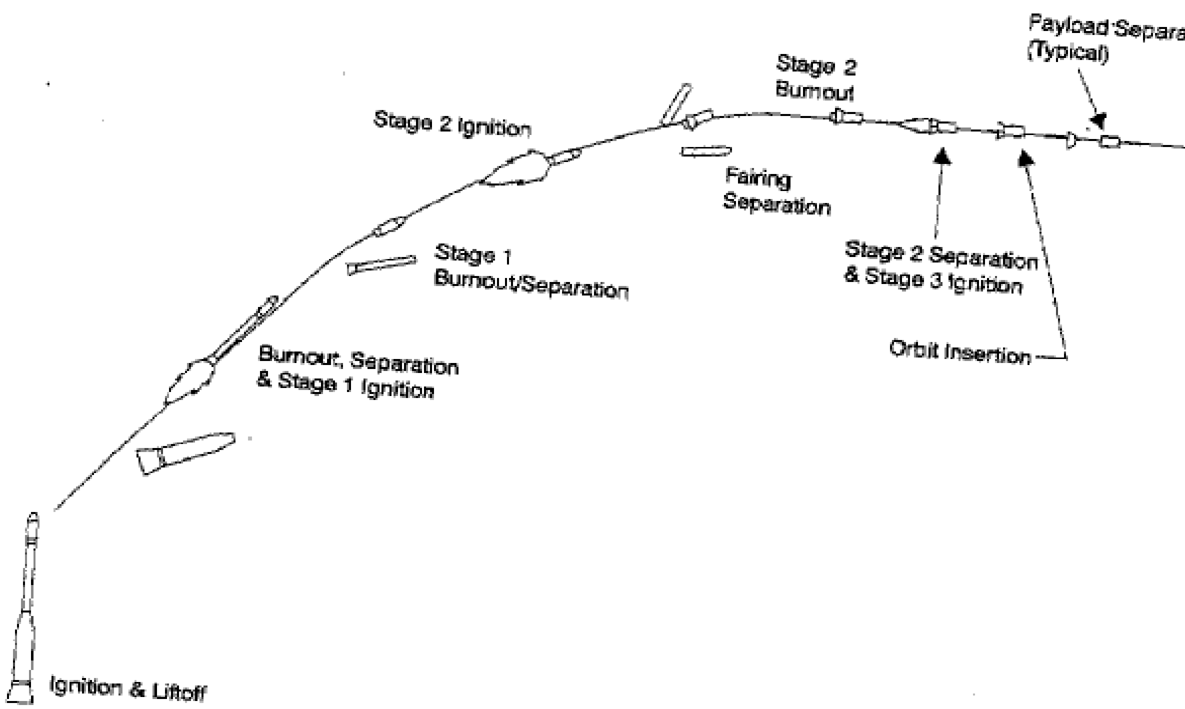
FIGURE 2-1
TYPICAL FLIGHT SEQUENCE FOR AIR-BASED LAUNCHES OF VEHICLES CARRYING SMALL PAYLOADS



Typical Flight Sequence for a Small Capacity Launch Vehicle (Air-based Launch)

Time (Min:Sec)	Event
00:00	Launch
00:05	Stage I Ignition
01:16	Stage I Burnout/Separation
01:35	Stage II Ignition
01:52	Fairing Separation
02:46	Stage II Burnout
09:54	Stage III Ignition
11:00	Orbit Insertion

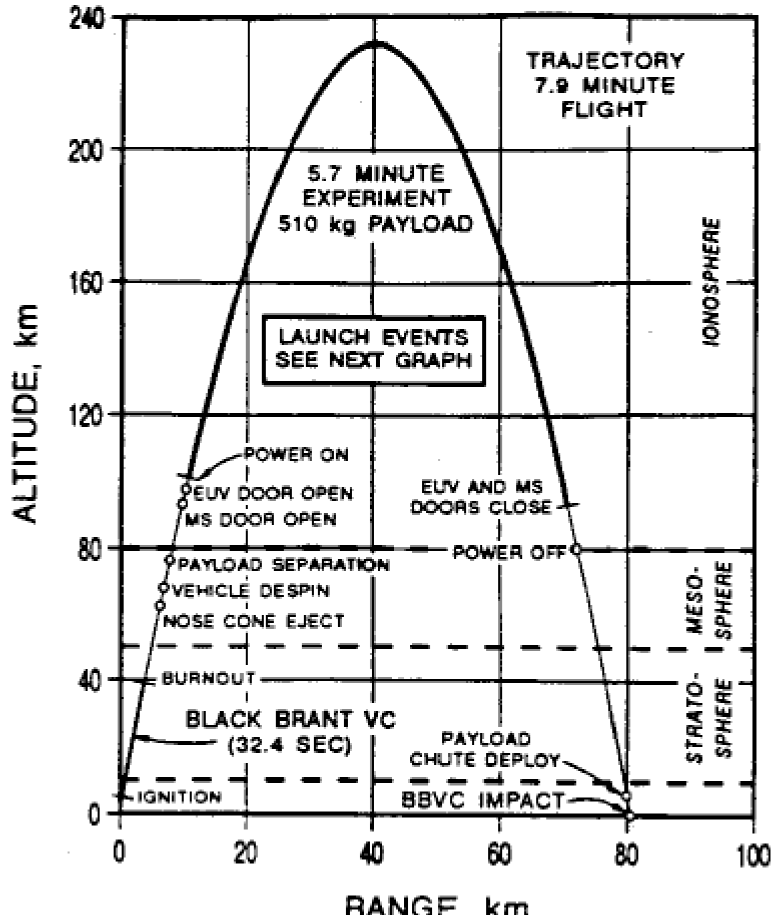
FIGURE 2-2
TYPICAL FLIGHT SEQUENCE FOR LAND-BASED LAUNCHES OF VEHICLES CARRYING SMALL PAYLOADS

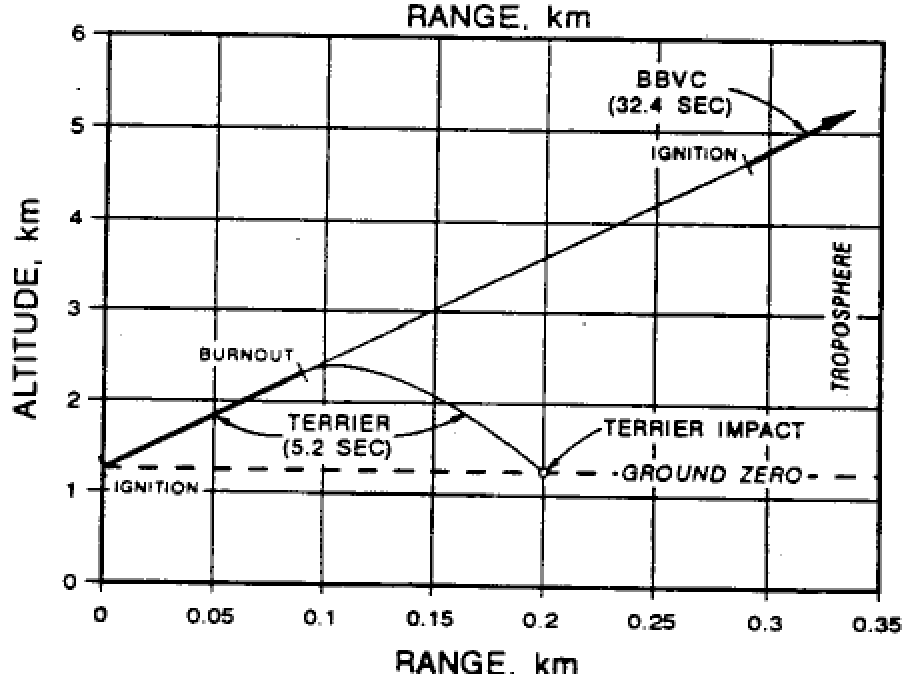


Typical Flight Sequence for a Small Capacity Launch Vehicle (Ground-based Launch)

Time (Min:Sec)	Event
00:00	Ignition and Liftoff
01:21	Burnout, Separation/Stage 1 Ignition
02:34	Stage I Burnout/Separation
02:39	Stage II Ignition
02:42	Fairing Separation
04:00	Stage II Burnout
11:40	Stage II Separation/Stage III Ignition
12:50	Orbit Insertion
13:50	Payload Separation

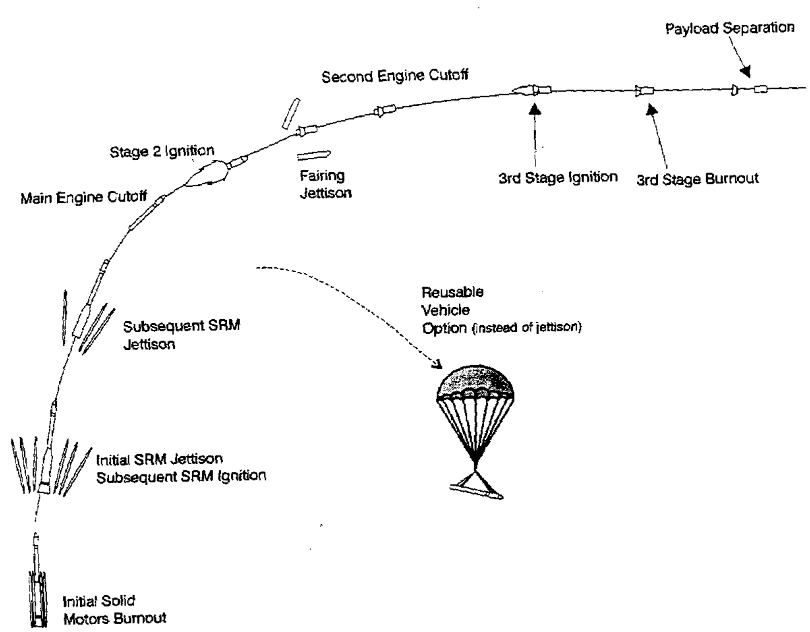
FIGURE 2-3
TYPICAL FLIGHT PROFILE FOR AN UNGUIDED SUBORBITAL LAUNCH VEHICLE





Source: National Aeronautics and Space Administration. Draft Supplemental Environmental Impact Statement for Sounding Rocket Program. August 1994, p. 2-54.

FIGURE 2-4
TYPICAL FLIGHT PROFILE FOR A LAND-BASED MEDIUM OR INTERMEDIATE CAPACITY LV[g]

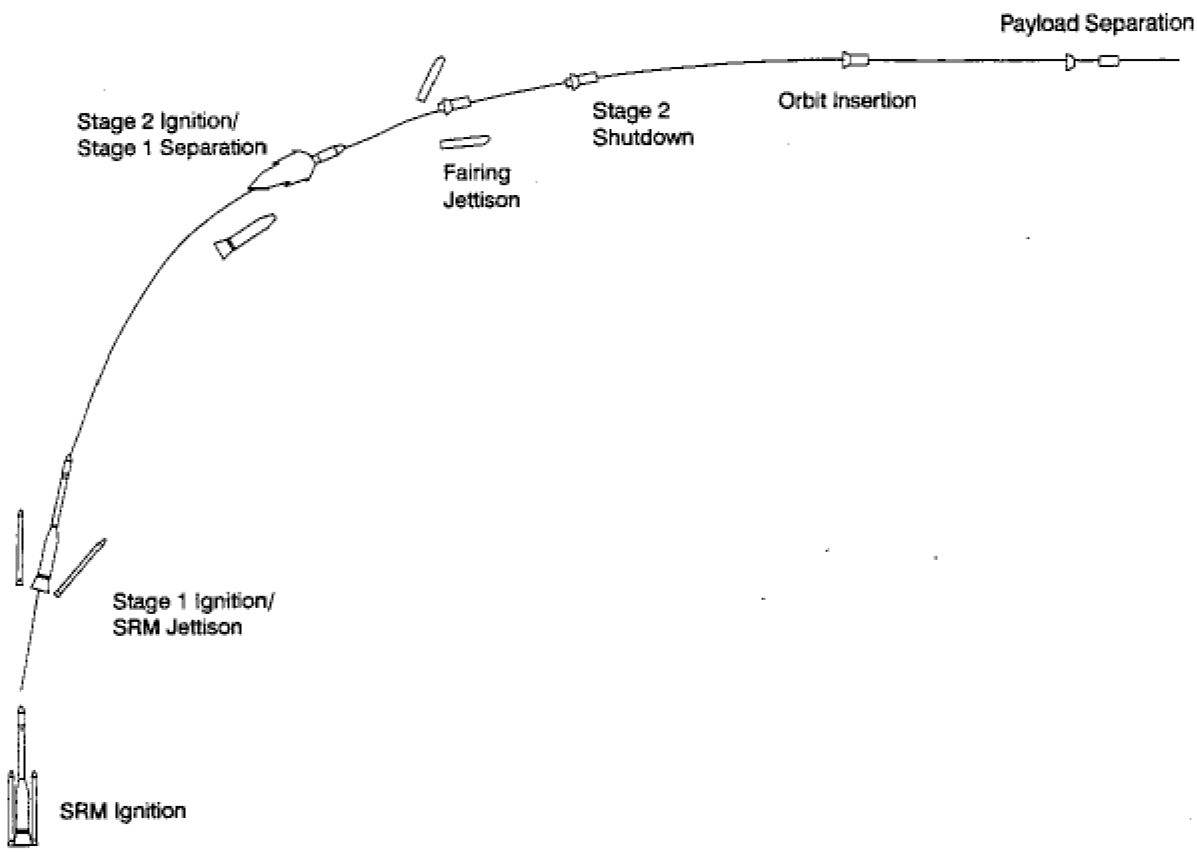


Typical Flight Sequence for a Medium and Intermediate Capacity Launch Vehicle

Time (Min: Sec)	Event
00:00	Main Engine and Initial SRM Ignition
01:06	Initial SRM Jettison/Subsequent SRM Ignition
02:10	Subsequent SRM Jettison
04:25	Main Engine Cutoff
04:38	Stage II Ignition
05:02	Fairing Jettison
21:51	Second Engine Cutoff
23:21	Stage III Ignition
24:48	Stage III Burnout
26:41	Payload Separation

[g] Note: the graphic of the flight sequence does not include a possible stage two engine shut down and subsequent re-start which could occur during this stage of flight.

FIGURE 2-5
TYPICAL FLIGHT PROFILE FOR A LAND-BASED HIGH CAPACITY LV



*Note: This schematic only depicts this high capacity vehicle deploying a single payload. However, high capacity vehicles can carry more than one payload.

Typical Flight Sequence for a High Capacity Launch Vehicle

Time (Min: Sec)	Event
00:00	Stage 0 Ignition (SRM Ignition)
01:48	Stage I Ignition/SRM Jettison
04:30	Stage II Ignition/Stage I Separation
04:40	Payload Fairing Jettison
08:14	Stage II Shutdown
08:30	Orbital Insertion
08:30+	Payload Separation

2.3. *Alternatives Considered*

2.3.1. Non-Solid Propellant Alternative

The FAA considered several alternatives to the preferred alternative including the non-solid propellant alternative in which the FAA would preferentially license only those vehicles that use liquid or hybrid fuels. Under this alternative, no vehicles using solids for launches would be licensed by the FAA. Table 2-4 shows that the majority of vehicles used for licensed launches for all payload sizes rely on the use of solids for their propellant systems. Implementing the non-solid propellant alternative would eliminate the majority of licensed launches by existing launch service providers. This alternative is therefore considered to be infeasible and although considered, is not specifically assessed in the remainder of the document.

2.3.2. More Environmentally-Friendly Vehicles Alternative

Under this alternative, the FAA would not license any launches until such time that a new LV is designed that causes no adverse impacts to the environment. This alternative would prevent all current and proposed U.S. launches from being licensed. Implementing this alternative would prevent U.S. launch service providers from launching any payloads in the foreseeable future. Therefore, all U.S. companies who want to launch satellites would be forced to rely on foreign countries to launch their satellites. This would put additional pressure on foreign markets to keep up with the increased demand. This alternative is not assessed further in the document because it does not comport with the statutory mandate or mission of the FAA and is therefore not considered to be a feasible alternative.

2.3.3. Composite Vehicle Construction Alternative

Under this alternative, the FAA would preferentially license those launches using vehicles that are entirely constructed of composite or exotic lightweight materials to make the vehicle lighter and therefore, not require as much fuel to reach orbit. It should be noted that all existing launch vehicles are composed of some composite materials (i.e., fuel tanks). However, vehicles composed completely of composite materials do not currently exist and there are no realistic plans to develop them in the near future. Therefore, until U.S. launch service providers research, develop, and test this type of vehicle all U.S. companies that want to launch satellites would be forced to rely on foreign countries to launch their satellites. This alternative is not considered to be a feasible option for the FAA to implement and therefore is not assessed further in the document.

2.3.4. More Environmentally-Friendly Propellant Combinations Alternative

Under this alternative, the FAA would preferentially license those launches using vehicles that produce less harmful tropospheric and stratospheric air emissions of HCl and Al_2O_3. These types of emissions are associated with SRM propellants. Therefore, this alternative would be to preferentially license launches of LVs with no SRMs or combinations of SRMs and liquids. This alternative was retained for detailed study, see Section 2.4.1 below.

2.3.5. No Action Alternative

Under the no action alternative, the FAA would not issue licenses for launches. Therefore, no U.S. launch companies would be able to conduct licensed launch operations. U.S. companies would need to contract the services of foreign launch providers to insert their satellites into orbit. This alternative was retained for detailed study, see Section 2.4.2 below.

2.3.6. Launch Licensing Alternative

This is the preferred alternative under which the FAA would license launches. Licenses would be issued in accordance with the specifications set out in 49 U.S.C. Subtitle IX, ch. 701 and supporting regulations. Under this alternative, some site-specific NEPA analysis would still be required, prior to issuing launch licenses. This alternative was retained for detailed study, see Section 2.4.3 below.

2.4. Alternatives to be Considered in Detail

Based on a systematic evaluation of the full range of potential alternatives, three alternatives will be carried forward for detailed environmental impact assessment, the more environmentally-friendly propellant combinations alternative, the no action alternative, and the launch licensing alternative. The more environmentally-friendly propellant alternative will be examined in detail in Section 2.4.1 below. The no action alternative will be examined in detail in Section 2.4.2 below. The launch licensing alternative will be examined in detail in Section 2.4.3 below.

2.4.1. More Environmentally-Friendly Propellant Combinations Alternative

In its analysis of possible alternatives, the FAA considered options for preferentially licensing launches using LVs with environmentally friendly attributes, relative to LVs with neutral or more environmentally harmful attributes.

Additional environmental characteristics that the FAA considered but rejected include:

- Payload capacity. Air emissions from LVs vary by payload capacity. Lower-capacity LVs tend to use less powerful engine systems and have lower emissions as compared to higher-capacity LVs. Payload capacity is also related to propellant system.

- Noise level. Some LVs produce less harmful noise as perceived by human and/or wildlife receptors relative to other LVs. Perceived noise level may be a function of the vehicle engine system size, noise control measures implemented during launch, and the location and sensitivity of receptors. In general, high capacity vehicles with the largest engines produce the most noise; however, if the launch site is in a very remote area, there may be very few receptors nearby to be affected by the noise.

- Type of launch platform. Some LVs have launch profiles that may result in less environmental effects than other launch profiles. For example, it is possible that a sea-based launch platform may have fewer environmental effects on some biological resources (e.g., no soil or vegetation impacts) and human populations (e.g., less human noise exposure) than a ground-based launch platform, but more effects on other biological resources (e.g., perhaps a heightened risk of a marine animal strike). The magnitude and trade-offs of environmental effects produced would be a function of the site-specific characteristics of sensitive biological resources and human populations at the launch sites being considered.

The environmental characteristic that the FAA considered and determined needed more detailed analysis is:

Air Emissions. Air emissions from LVs are determined mainly by propellant type. The environmentally harmful chemicals emitted to the atmosphere vary by the type of propellant used. For example, most propellant systems produce CO_2, which is a greenhouse gas. Greenhouse gas emissions in the troposphere and stratosphere are of concern as they contribute to global warming by trapping re-radiated energy in the atmosphere (e.g., water vapor, carbon dioxide, methane, nitrous oxide, ozone, chlorofluorocarbons, hydrofluorocarbons, and perfluorinated carbons). Hybrid and LO_x-RP1 propellant systems produce more CO_2 than solid propellant systems, however, they emit less NO_x than systems using hypergolic propellants. NO_x is an ozone depleting substance and a contributor to smog. Only solid rocket motors (SRMs) produce tropospheric and stratospheric emissions of HCl and aluminum oxide (Al_2O_3). HCl is a toxic gas that can destroy stratospheric ozone and is defined by the EPA as a Hazardous Air Pollutant. Al_2O_3 is a particulate that can serve as a site for atmospheric reactions depleting ozone. Emissions of HCl and Al_2O_3 are perceived as more significant, immediate environmental threats than the greater amount of CO_2 emissions produced by hybrid and LO_x-RP1 propellant systems (see Appendix A). Emissions from hydrogen peroxide propulsion systems are expected to be similar to those from LO_x/kerosene systems.

Thus, for this analysis, the alternative option of "More Environmentally-Friendly Propellant Combinations" was defined as licensing launches of vehicles that emit less HCl and Al_2O_3 into the troposphere and stratosphere. Because these emissions are clearly linked to SRMs, an alternative to the preferred alternative is to preferentially license launches using LVs with no SRMs or combinations of SRMs and liquids in the troposphere or stratosphere. LVs powered by SRMs in the troposphere or stratosphere are excluded. While it may be environmentally preferable to limit all SRM usage, this alternative is not feasible because current technology requires a combination of liquids, cryrogenics, and SRM systems to launch a payload into geosynchronous orbit. Therefore, preferentially licensing launches of LVs with no SRMs would exclude all larger, three-stage GEO launch vehicles. Furthermore, conclusive data and analysis regarding the specific impacts of emissions from multi-propellant or hybrid propulsion systems currently do not exist. Thus, this analysis relies on existing, available data on emissions from current propellant systems. Ongoing U.S. Air Force, NASA and industry research in this area may alter the future understanding of the cumulative atmospheric impacts of multi-propellant propulsion systems and the relative atmospheric impacts of existing types of propellant systems.

Preferentially licensing those launches with LVs that are not solely propelled by SRMs would reduce the total number of launches projected through 2010 to 189; see Table 2-6. The number of launches using liquid, liquid/solid, or hybrid propellant systems was assumed to remain unchanged under this alternative. Thus, the total number of FAA-licensed launches in the U.S. (i.e., programmatic launches) would decrease substantially under this alternative. It was assumed that the decrease in U.S. licensed launches using only solid propellants would be compensated for by an increase in these launches elsewhere in the world.

TABLE 2-6
TOTAL NUMBER OF U.S. LICENSED LAUNCHES BY LAUNCH CAPACITY CATEGORY FOR THE YEARS 2000-2010: MORE ENVIRONMENTALLY-FRIENDLY PROPELLANT COMBINATIONS ALTERNATIVE

	NUMBER OF U.S. LAUNCHES **2000-2010**
SMALL CAPACITY <2,000 lb GTO or < 5,000 lb LEO	0
MEDIUM CAPACITY 2,000-3,999 lb GTO	22
INTERMEDIATE CAPACITY 4,000-8,999 lb GTO or >5,000+ lb LEO	75
HIGH CAPACITY 9,000-10,000+ lb GTO	92
TOTAL	**189**

2.4.2. No Action Alternative

Under the no action alternative, the FAA would not issue licenses for launches. Because 49 U.S.C. Subtitle IX, ch. 701 requires launches to be licensed, the U.S. launch industry would be unable to provide licensed launches regardless of launch location. Chapter 701 requires the FAA to license a launch if the applicant complies and will continue to comply with chapter 701 and implementing regulations. 49 U.S.C. § 70105. One of the purposes of chapter 701 is to provide that the Secretary of Transportation, and therefore the FAA, pursuant to delegations, oversees and coordinates the conduct of launch and reentry, and issues and transfers licenses authorizing these activities. 40 U.S.C. § 70104 (b)(3). The agency has the authority to prevent a launch if it decides that the launch would jeopardize public health and safety, safety of property, or national security, or a foreign policy interest of the United States. 49 U.S.C. § 70104 (c). Not licensing any U.S. launches would not be consistent with the purposes of chapter 701 in this context.

In any event, refusing to license any U.S. launches suffers from other drawbacks as well. It is possible that worldwide demand for launches would decline if the U.S. were no longer in the commercial market. However, it is more likely that companies in need of launch services would procure these services from another country. It is likely that U.S. telecommunications companies and other U.S. space users would seek other sources to avoid the risk of delaying launch of their satellite systems and falling behind global competition. Similarly, it is reasonable to assume that scientific and microgravity payloads would also seek alternative launch resources. As a result, U.S. satellites and payloads would still be placed in orbit, but on vehicles launched by foreign companies or countries. This, in turn, could also pose a scheduling problem for U.S. payloads because current international agreements limit the number of U.S. commercial payloads that can be flown on foreign launchers. Another scheduling issue could arise with lag time needed to construct additional launch facilities in the alternate countries.

2.4.3. Launch Licensing Alternative

This alternative has been identified as the preferred alternative. Under this alternative the FAA would issue launch licenses to U.S. companies to conduct launch operations. The licensing process would follow specifications set out in the statute and supporting regulations. Implementing this alternative would allow U.S. licensed launch providers to meet the needs of U.S. companies that want to launch satellites; thus, decreasing the need for U.S. companies to look to foreign launch providers to launch U.S. satellites. This alternative would also leave the opportunity open to U.S. government satellites being launched commercially.

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3. DESCRIPTION OF THE EXISTING ENVIRONMENT

This section discusses the existing environment that could be potentially impacted by an LV launch given the flight profile and the environment in the immediate vicinity surrounding potential licensed launch locations. The discussion begins with an examination of the Earth's atmosphere, including its regions and boundaries, as related to the flight profiles of the categories of LVs. Then, the baseline noise environment is discussed. Finally, environments near existing and proposed licensed launch locations on the Earth's surface are described.

3.1 The Atmosphere

There are four principal layers in the Earth's atmosphere: troposphere, stratosphere, mesosphere, and ionosphere. They are generally defined by temperature, structure, density, composition and degree of ionization. Ionization refers to the electric charge associated with the atmospheric layers, this may be either a positive or a negative charge. The approximate altitude of these layers is provided in Table 3-1.

TABLE 3-1
ALTITUDE RANGE FOR VARIOUS ATMOSPHERIC LAYERS

	Troposphere	Stratosphere	Mesosphere	Ionosphere
Altitude Range	Surface to 10 km	10 to 50 km	50 to 80 km	80 to 1,000 km

3.1.1 Troposphere

The troposphere extends from the Earth's surface to approximately 10 kilometers. It is the turbulent and weather region containing 75% of the total mass of the Earth's atmosphere. It is characterized by decreasing temperature with increasing altitude. The major components of the troposphere are nitrogen (N_2) (76.9%) and oxygen (O_2) (20.7%). Other components of lesser concentration include water vapor (1.4% in the lower atmosphere), argon (Ar), carbon dioxide (CO_2), nitrous oxide (N_2O), hydrogen (H_2), xenon (Xe), and ozone (O_3). Certain emissions or toxic contaminants, from both human and natural activities, can cause acute health exposure, degrade ambient air quality, can form acid rain that is deposited on Earth, or can travel to the upper atmosphere to contribute to global warming and ozone depletion. Approximately 10% of the Earth's ozone is in the troposphere.[7] Ozone at the Earth's surface is of great concern because it can directly damage life, including crop production, forest growth, and human health. Ozone is also a key ingredient for smog production.[8]

Ambient air quality in the U.S. in the lower troposphere is regulated through the National Ambient Air Quality Standards (NAAQS) established by the Clean Air Act (CAA). Maximum airborne concentrations are specified for the following criteria pollutants: ozone, carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), particulate matter of 10 microns or less in diameter (PM_{10}), particulate matter of 2.5 microns or less in diameter ($PM_{2.5}$), and lead (Pb). The standard for $PM_{2.5}$ was proposed by the EPA; however, implementation was suspended by the U.S. Court of Appeals.[h] Particulate matter can include small liquid or solid particles. Primary air quality standards provide airborne concentration limits based on human health requirements. Exceedences of these concentrations are determined over particular averaging periods (e.g., one-hour, 24-hours, annually). These averaging periods vary for different pollutants and several criteria pollutants have standards for more than one

[h] The U.S. Supreme Court recently (February 2001) unanimously upheld the constitutionality of the CAA as interpreted by EPA in the 1997 ambient air quality standards for ozone and particulate matter.

averaging period. Table 3-2 provides NAAQS Primary Standards. The NAAQS standards have been provided here in the PEIS to serve as a benchmark from which to assess the potential impacts that launch emissions could have upon air quality in general. It is recognized that at this time EPA does not regulate launch vehicle emissions.

TABLE 3-2
NATIONAL AMBIENT AIR QUALITY STANDARDS[i]

Pollutant	Unit	Maximum	Average Time Period
Ozone	Ppm	0.12	1 hour
CO	Ppm	9 35	8 hours 1 hour
NO_2	Ppm	0.05	AAM
SO_2	Ppm Ppm	0.03 0.14	AAM 24 hours
PM_{10}	μg/m^3	150 50	24 hours AAM
$PM_{2.5}$	μg/m^3	65 15	24 hours AAM
Pb	μg/m^3	1.5	Quarterly
ppm = parts per million AAM = Annual Arithmetic Mean μg/m^3 = micrograms per cubic meter			

The Environmental Protection Agency (EPA) specifies whether certain areas attain or meet air quality standards. Nonattainment areas do not meet the NAAQS, whereas attainment areas do meet these air quality standards. EPA addresses mobile sources, such as aircraft, in its assessments of attainment status, but does not address LVs. Aircraft emissions are addressed from the surface to 3,000 feet above ground level.[9] There are many counties in the U.S. that are not in attainment for various pollutants. Ozone nonattainment areas are classified into one of five designations, based on the severity of air pollution. The designations, in order of increasing severity, are: Marginal, Moderate, Serious, Severe, and Extreme. Only the Los Angeles area is in an extreme nonattainment area for ozone. Carbon monoxide nonattainment areas are classified according to the severity of the pollution. Although not covered by EPA under NAAQS, LV emissions, especially potentially large quantities of criteria pollutants, should be considered in any environmental impact analysis.

Under Title V of the Clean Air Act Amendments of 1990, facilities must obtain permits to release regulated air pollutants including criteria pollutants and hazardous air pollutants (HAPs). EPA regulates 188 HAPs, which are chemicals that pose potential health risk to exposed persons. Hydrazine, MMH, UDMH, N_2O_4, and HCl are all EPA-listed HAPs. Therefore, operators of launch sites that emit any of these chemicals may be required to obtain any necessary permits from EPA under Title V. Emissions sources covered by the CAA would include pre- and post- launch activities, such as

[i] The information in this table was taken from the EPA website (http://www.epa.gov/airs/criteria.html)

construction, ground, vehicle, and fueling emissions. The EPA does not regulate LV emissions during flight.

3.1.2 Stratosphere

The stratosphere extends from approximately 10 kilometers to 50 kilometers above the Earth's surface. Unlike the troposphere, the stratosphere is characterized by higher temperatures at the higher altitudes.[10] The stratosphere contains a critical ozone layer for protecting against damage to Earth's biological organisms from ultraviolet sunlight. Most atmospheric ozone (90%) is found in the stratosphere. The highest ozone concentrations are found in the lower stratosphere. Ozone is continually created and destroyed by naturally occurring photochemical processes[11] and its concentration fluctuates seasonally (25%) and annually (1-2%).[12, 13] Ozone is made up of three oxygen atoms and is generated by the action of sunlight to combine an O_2 molecule with an atom of oxygen. Atomic oxygen is produced by photolysis, or the use of radiant energy to produce chemical changes, of molecules of oxygen, nitrogen dioxide, or ozone. Ozone can be depleted by compounds that contain various elements, most notably chlorine, fluorine, hydrogen, and nitrogen. Aluminum oxide (particulates) and soot may also provide a reaction surface for the destruction of ozone. NO_2 is also important in the stratosphere; it functions as a major catalyst for ozone destruction at those altitudes.

3.1.3 Mesosphere

The mesosphere extends from 50 kilometers to 80 kilometers above the Earth's surface. The upper boundary of the ozone layer occurs at the base of the mesosphere. As a result, the temperature in the mesosphere decreases with altitude. The mesosphere is characterized by varied wind speeds and directions.[14]

3.1.4 Ionosphere

The ionosphere (also called the thermosphere) extends roughly from 80 to 1,000 km (50 to 620 miles) from the surface of the Earth. It is the first part of the Earth's upper atmosphere. The ionosphere is characterized by its high ion (electrically charged particle) and electron density, and is composed of several layers with differing properties.

The major neutral (non-charged) constituents of the ionosphere are atomic oxygen (O), N_2, and O_2, and minor constituents are NO, atomic nitrogen (N), helium (He), Ar, and CO_2. These neutral constituents are strongly influenced by the motions of plasma (ionized gas). This region is a very high vacuum compared to the atmosphere at the Earth's surface, but it still causes some drag on satellites orbiting within it.

The boundaries between the different layers within the ionosphere are indistinct. The lowest region is the E layer, occurring between about 80 and 140 km. The NO^+ ion is the dominant ion in the E layer. The F1 and F2 layers occur in the general area between 140 and 1,000 km, and the dominant ion in these layers is the O^+ ion. The F2 layer is always present, and contains the region of highest electron concentration in the ionosphere (at approximately 300 km). Above the maximum region of electron concentration in the F2 layer, the electron concentration decreases continuously out to several Earth radii, at which point the Earth's magnetic field and the protonosphere (the outermost portion of the ionosphere) become indistinct from the solar wind or space.

The different layers of the ionosphere are particularly important to low frequency radio communications. Radiation from the visible spectrum (e.g., aurora) originates in this region. The ionosphere is influenced by solar radiation, variations in the Earth's magnetic field, and the motion of the upper atmosphere. Because of these interactions, the systematic properties of the ionosphere vary greatly with geographic latitude and time (diurnally, seasonally, and over the approximately 11-year solar cycle).[15]

3.1.5 Orbital Debris Reentering Earth's Atmosphere

Orbital debris is defined as man-made space debris that remains in Earth orbit during its lifetime.[16] This debris has no impact on the human environment as defined by NEPA unless and until the debris enters the Earth's atmosphere. Unlike meteoroids, or natural debris, which are part of the space environment and sweep through Earth orbital space at an average speed of 20 km/sec, orbital debris remains in Earth orbit creating potential acute and cumulative impacts on satellites and other space objects. Three types of orbital debris are of concern on orbit: (1) objects larger than 10 cm in diameter, commonly referred to as large objects, which are routinely detected, tracked, and cataloged; (2) objects between 1 and 10 cm in diameter, commonly referred to as risk objects, which cannot be tracked and cataloged; (3) objects smaller than 1 cm in diameter, commonly referred to as small debris or in some sizes microdebris. The interaction among these three classes combined with their long residual times in orbit creates concern that there may be collisions producing additional fragments and causing the total debris population to grow, which may increase the chance of reentry into Earth's atmosphere.

Debris in each of these classes can be generally classified into four source categories. Operational debris are composed of inactive payloads and objects released during satellite delivery or satellite operations, including lens caps, separation and packing devices, spin-up mechanisms, empty propellant tanks, spent and intact vehicle bodies, payload shrouds, and a few objects thrown away or dropped during manned activities. Fragmentation debris result from either collisions or explosions. Deterioration debris is very small debris particles created by the gradual disintegration of spacecraft surface as a result of exposure to the space environment, including paint flaking and plastic and metal erosion. Solid rocket motor ejecta results from the ejection of thousands of kilograms of aluminum oxide dust from solid rocket motors into the orbital environment.[17]

The effects of orbital debris impacts depend on velocity, angle of impact, and mass of the debris. For debris of sizes less than 0.01 cm, surface pitting and erosion are the primary effects.[18] Over a long period of time, the cumulative effect of individual particles colliding with a satellite might become significant since the number of particles in this size range is very large in Low Earth Orbit. Although solid rocket motor ejecta are very small, (less than 0.01 cm) long-term exposure of payloads to such particles is likely to cause erosion of exterior surfaces, chemical contamination, and may degrade operations of vulnerable components such as optical windows and solar panels.[19] Debris of sizes 0.01 cm to 1 cm produce serious damage which, depending upon system vulnerability and defensive design provision, can result in structural damage to the satellite.[20] Mitigation measures can be employed to shield against debris particles up to 1 cm in diameter. Objects larger than 1 cm can produce catastrophic damage.

3.2 Noise Sources and Effects

To describe noise and its effects, several terms will be used, as presented below.

Sound. Sound is an energy source produced by vibrating the air or other media. This vibration is made up of many frequencies. The sensitivity of the human ear, or our ability to hear sound, varies with frequency. Humans are most sensitive to sound in the 2,000 to 4,000 hertz (Hz) range. Hertz is a measure of the number of vibrations per second. This will become important when discussing sonic booms, and other single event noises, that produce a large amount of their sound energy in the lower frequency range. Sound is measured in decibels (dB) which is a unit for describing the ratio of two powers or intensities, or the ratio of a power to a reference power.

dBA. This is the "A" weighted sound level, a unit used to show the relationship between the interfering effect of a noise frequency, or band of noise frequencies, and a reference power level of - 85 dBm (decibels relative to one milliwatt). The dB noise scale is a logarithmic scale and therefore the perceived levels increase more sharply than on a linear scale (i.e., a 60dB noise is not twice a loud as a 30dB noise, but is in fact many times as loud.) It is used to characterize noise as heard by the human ear. It accomplishes this by artificially lowering the sound at lower and higher frequencies, where the human ear is less sensitive to sound reception. The dBA is used to assess human reaction to single event noise and is averaged over a 24 hour period to predict community reaction. Single event noise (SEL) is usually reported as maximum dBA. LAMAX is another metric used to describe the maximum dBA noise level. The 24 hour noise level is reported as L_{dn}, which is described below.

psf. Pounds per square foot is a measure of pressure. Sonic booms produce pressure waves that can cause damage. The damage is a function of the pressure produced. Pressure has also been correlated to human response to sonic booms.

L_{dn}. This is the day-night noise level over a 24 hour period. It is reported in dBA, and is used to predict human annoyance and community reaction to unwanted sound (noise). Since humans are typically more sensitive to noise in the evening, the L_{dn} places a 10 dBA penalty on noise produced between the hours of 10 p.m. and 7 a.m.

Noise impacts are very site specific; the closer a receptor is to a noise source, the greater the potential impact. Therefore, the remainder of this section presents a range of scenarios and values regarding noise and its effects.

3.2.1 Existing Noise Environments

Noise is most closely associated with land use. An urban environment is noisier than a suburban environment, and a suburban environment is noisier than a rural environment. Locational and seasonal changes are most readily apparent in rural and wilderness areas where natural noise sources predominate. For example, during the summer season insects can have a substantial effect on noise levels. In comparison, arctic winters are very quiet in the wilderness. Wind can predominate noise levels, especially in forested areas.

The following dBA measurements were recorded at existing launch facilities which encompass various environmental settings:

- remote desert environments[j]: 22-38 dBA[21]
- interstate interchanges (non-urban)[k]: 55-70 dBA[22]
- Marshall Space Flight Center (wooded area with insects dominating the higher reading)[l]: 40-54 dBA[23]
- Vandenberg Air Force Base[m]: 48-67 dBA[24]
- Edwards Air Force Base (with some areas off base at 80 dBA)[n]: 65-85 dBA.[25]
- White Sands Missile Range (WSMR)[o]: main post 55-65 dBA; property boundary 45-55 dBA; and at nearby San Andreas National Wildlife Refuge 45 dBA.[26]
- Eastern Range[p]: 60-80 dBA.[27]
- Kodiak Launch Complex[q]: 95 dBA approximately 6,250 feet from the center of the pad, decreasing to 70 dBA at a distance of 5.6 to 15 miles from the launch pad.[28]

Table 3-3 presents a broader range of L_{dn} values by land use type.

TABLE 3-3
EXAMPLES OF OUTDOOR DAY-NIGHT AVERAGE SOUND LEVELS AT VARIOUS LOCATIONS

Outdoor Location	L_{dn} in decibels
Apartment next to freeway	88
¾ mile from touchdown at major airport	86
Downtown with some construction activity	79
Urban high density apartment	78
Urban row housing on major avenue	68
Old urban residential area	59
Wooded residential	51
Agricultural crop land	44
Rural residential	39
Wilderness ambient	35

Source: U.S. EPA. Protective Noise Levels: Condensed Version of EPA Levels Document. November 1978.

3.2.2 Noise Sources

This section discusses the potential noise sources associated with licensed launches that could pose impacts to nearby sensitive receptors. The generation of sonic booms is an effect of flight speeds in excess of the speed of sound. The intensity of sonic booms produced by LVs is a function of vehicle

[j] Estimate, no other specifics given.
[k] Monitoring data, no other specifics given.
[l] One hour monitoring.
[m] Twenty-four hour monitoring.
[n] Monitoring data, no other specifics given.
[o] Estimate, no other specifics given.
[p] Daytime monitoring.
[q] Rocket noise levels from launch of USAF atmospheric interceptor technology (ait) test vehicles.

size, configuration, and velocity. Noise from launches has been described as intense, infrequent, of relatively short duration, and composed predominantly of low frequencies.[29]

Launch Noise. Launches produce LV noise. Launch vehicle noise is produced as the propellant is consumed and exhausted into the atmosphere. Various studies have estimated launch noise at various distances from the source.[30, 31, 32, 33, 34] Although not always specified, these data appear to represent maximum dBA levels. Using atmospheric attenuation, the extrapolation of these various values out to three miles from the pad, results in a noise range of approximately 80 to 120 dBA for all launch vehicles. If one looks at LVs that might be used for licensed launches, the range narrows to approximately 80 to 100 dBA. This seems to be a reasonable estimate as only a limited number of LVs under consideration have a high payload capacity. It has been estimated that most of this noise can be heard for 1 minute.[r,35] It would sound like “distant rumble” in communities surrounding launch areas and could be “noticeably heard” at distances greater than six miles from the launch site.[s,36]

Results of testing at Vandenberg AFB, between 1994 and 1996 confirm the above and yield further insight into this issue. Noise from the Taurus LV measured an SEL of 108.5 dBA at 7,350 feet from the launch pad. Maximum noise was in the 50 Hz range and lasted from approximately 5 to 15 seconds after launch.[t] The Delta II launch in 1995 was recorded at four monitoring sites. The closest was 1,500 feet from the launch pad and recorded an SEL of 130 dBA. The farthest was 4,000 feet away and recorded an SEL of 122 dBA. At all sites noise above 100 dBA could be heard from approximately 6 to 30 seconds after the launch, with the farthest site receiving the sound approximately 2 seconds after the closest site.[u]

During a 1996 Titan IV launch, measurements were taken in the Channel Islands, 30 to 40 miles from the launch pad. SEL readings were 71 to 74 dBA. Maximum frequency was 10 to 50 Hz and maximum noise could be heard from 5 to 25 seconds after launch. Noise in the 10 to 50 Hz range was approximately 40 dBA higher than noise in our most sensitive range of 2,000 to 4,000 Hz.[v]

Flight Noise. Moving LV noise is governed by the combustion process, dynamics of the exiting gases, and flight parameters. One modeled case for a generic reentry vehicle indicated a maximum of 65 dBA at approximately four miles from the launch pad.[37] As the vehicle ascends, two principles combine to reduce the ground noise levels: (1) separation distance increases; and (2) the air becomes thinner and therefore less capable of transmitting noise.

Sonic Boom. Sonic booms have two potential effects: (1) annoyance and possible health impacts to humans and wildlife, and (2) possible structural damage. Sonic booms are perceived to constitute a potential risk to public health and safety because of the unexpected nature of the physiological responses they may initiate. Structural damage due to sonic booms is linked to the pressure wave (called overpressure) that is created. Overpressure is the transient pressure, usually expressed in pounds per square foot (psf), exceeding existing atmospheric pressure and manifested in the blast wave

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[r] Although not specified in the reference, this duration is believed to be experienced by persons located at or near the launch pad.

[s] Although not specified in the document, it is believed that the noise levels at this distance will exceed 70 dBA and “noticeably heard” means increases of 4 dBA or greater.

[t] The Aerospace Corporation. Taurus Launch Sound Levels at Varying Distance from the Launch Pad. August 1994.

[u] The Aerospace Corporation. Delta II Launch Sound Levels at Varying Distance from the Launch Pad: Delta II/Radarsat Launch from VAFB SLC-2W 4 November 1995. May 1996.

[v] The Aerospace Corporation. Channel Islands Noise and Sonic Boom Environmental Measurement Report: Titan IV K-22 Vandenberg AFB Launch 12 May 1996. September 1996.

from an explosion. Overpressure has also been correlated to human effects. Therefore, in addition to noise measurements, overpressure measurements in psf will be used to help describe impacts.

As an LV moves through the air, the air is displaced to make room for the LV and then returns once the LV passes. In subsonic flight, a pressure wave precedes the LV and initiates the displacement of air around it. When an LV exceeds the speed of sound, referred to as Mach 1, the pressure wave can not travel faster than the speed of sound and cannot precede the vehicle, so the parting process is abrupt. As a result, a shock wave is formed at the front of the LV when the air is displaced around it and possibly at the rear where a trailing shock wave may occur.[38]

The shock wave that results from supersonic flight creates a sonic boom. A sonic boom differs from most other sounds because it is impulsive (similar to a gunshot), there is no warning of its impending occurrence to a potential receptor, and the magnitude of the peak levels is usually higher. Sonic booms from launches occur when vehicles are at supersonic speeds and have pitched over sufficiently for the boom to propagate on the ground. The generation of ascent-related sonic boom from LVs depends on the vehicle geometry and the exhaust plume size and drag. For suborbital vehicles, there would also be a sonic boom generated from the descent phase of the instrument package. The geometry of the re-entry of the instrument package affects the development of the sonic boom.[39] For a vehicle flying straight, the maximum sonic boom amplitudes would occur along the flight path and decrease gradually on either side; because of the effects of the atmosphere, there is a distance to the side of the flight path beyond which the sonic booms are not expected to reach the ground. This distance is normally referred to as the lateral cut-off distance.[40] In general, air density would also tend to reduce noise levels reaching the ground as the vehicle ascends, and other parameters such as vehicle shape, trajectory, and atmospheric conditions would affect the formation and propagation of sonic booms.

Atmospheric conditions play a significant role in modeling sonic booms. Space shuttle landings have been estimated to create an overpressure of 2.1 psf and a noise level of 134 dB (unweighted) at the launch pad.[41,] Sonic booms over WSMR have been estimated to be 115 dBA, creating 50 to 60 dBA noise levels 5 to 10 miles away from the launch pad. The Atlas II was modeled with results indicating 121 to 134 dB (unweighted) and an over pressure of 0.5 to 2 psf at a distance of approximately 5 miles from the launch pad.[42] Other estimates suggest sonic booms may begin at 1.1 to 1.5 miles from the launch pad[43] and at 21 to 35 miles down range, resulting in 50 to 100 dBA.[44] The modeling of a generic reentry vehicle also reported that the sonic boom may last over a flight distance of 500 miles.[45] A sonic boom due to the overflight of a Titan IV from Vandenberg AFB was measured in the Channel Islands, 30 to 40 miles from the launch pad. At the center of the boom area there was a maximum pressure of 8.4 psf. The boom was also monitored at 12 other locations. Five locations recorded the boom and at a sixth it was heard. Pressure at these locations ranged from a high of 2.4 psf to a qualitatively estimated 0.1 psf.[w]

Sonic booms can also be created when stages fall back to Earth. Variable results have been produced from research in this area, including speculation that noise levels from the descent of stages are lower than those generated after vehicle take-off, as well as possibly being higher than those generated after take-off.[46] Noise data from the descent of test instrumentation from the USAF Atmospheric Interceptor Technology (ait) subsonic vehicle indicate that the maximum sonic boom (generated when the vehicle is at an altitude of approximately 2,400 meters (7,875 feet) and the instrumentation package is about to become subsonic) is about 3.2 psf at the water surface. In comparison, the maximum ascent

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[w] The Aerospace Corporation. Channel Islands Noise and Sonic Boom Environmental Measurement Report: Titan IV K-22 Vandenberg AFB Launch 12 May 1996. September 1996.

phase focus boom amplitude at the water surface for the test vehicle is 2.7 psf, with the trailing carpet boom diminishing rapidly as the vehicle gains altitude.[47]

Because launches often occur over water, underwater sonic boom propagation must also be considered as a potential noise impact from LVs. Research in this area indicates that the interaction between sonic boom waves with a surface wave train can profoundly influence the underwater propagation and noise penetrating power of the boom. In addition, sonic boom impacts are expected to be more severe in relatively shallow coastal water as compared to in the open sea, as a result of the amplification influence of the ocean floor. Furthermore, it appears that sonic boom noise underwater caused by an LV penetrates further and is more intense compared to supersonic aircraft overflight. Data from the Apollo 17 mission indicate that an LV plume can generate a sea-level signature length that may exceed two kilometers. Thus, these types of booms may represent a threat of physical and physiological impairment to marine animals in the vicinity of the water surface, particularly if these animals occur in the relatively restricted impact zone of the boom. In this impact zone, sonic boom shock strengths may reach 4 to 8 psf. [48]

Noise data from the USAF ait subsonic vehicle indicate that the ascent sonic boom for this vehicle, which has an overpressure of 2.7 psf, generates an underwater noise level of approximately 160 dBA for 200 milliseconds. The descent sonic boom from the instrument package returned from this vehicle generates an overpressure of 3.2 psf at the water surface for 200 milliseconds, and affects only an extremely small column of ocean.[49]

Accidents. There is very little information regarding noise levels during accidents, as most efforts to date have focused on launch noise. In particular, little research has been conducted on noise levels in the water during an accident. Underwater noise studies of accidents would need to consider the prevailing sea state and seafloor topography around the impact area, these data would be compared to established data from bioacoustic studies specific to marine animals. The primary focus of accident related noise studies has been on noise levels above the water. An explosion of an LV will produce significantly higher noise levels than those produced during normal operations. The U.S. Air Force predicted a noise level of 200 dBA and an overpressure of 4,000 psf at a distance of 100 feet for a Titan IV/Centaur vehicle. However, an exploding Titan IV should not be considered a typical scenario, because the Titan IV core vehicle uses hypergolic propellants. In a failure, hypergolic propellants deflagrate, instead of detonate, which produces less overpressure than an LV employing LO_x/RP1 or LO_x/LH_2. Thus, an accident involving a larger LV such as a Titan IV may produce less noise than a smaller LV, such as an Atlas or Delta.

3.3 United States LV Launch Environments (Earth's Surface)

The primary location of activity related to an LV launch is the atmosphere, thus, baseline atmospheric conditions have been detailed in Section 3.1. However, the Earth's surface would be affected by LV launches. This section discusses in broad terms the environmental characteristics of ecosystems representing licensed launch locations throughout the U.S. Six different types of environments are characterized. They include Mid-Atlantic Coastal, Southeastern Atlantic Coastal, Southwestern Desert-Arid, South Central California Pacific Coastal, Subarctic Pacific, and Ocean or Open-ocean environments. The purpose of including this discussion is to provide generic environmental characteristics against which impacts can be assessed in Section 5. The information below, however, does not purport to address all site-specific launch issues. Any required site-specific environmental documentation would be developed as needed. For example, the presence of threatened and endangered species is a highly site-specific determination, and a discussion of such species is not appropriate for this PEIS. However, other types of environmental characteristics can be meaningfully discussed for a local ecosystem. For example, the impacts of the presence or absence of wetlands and the types of surface water in the vicinity of potential launch locations. Wetlands, swamps, marshes, and bogs are described as including hydric soil conditions, and the plant species that survive in water saturated soil for extended periods of time. In addition, local atmospheric information, such as wind speed, temperature, and annual precipitation, is included to complement and complete the general characterization of the stratosphere presented in Section 3.1.1. To complete the discussion of the Earth's surface, subsection 3.3.5 provides an overview of the marine animals in the Atlantic and Pacific Oceans for consideration of potential impacts from jettisoned LV materials (e.g., SRMs, stages, payload fairings).

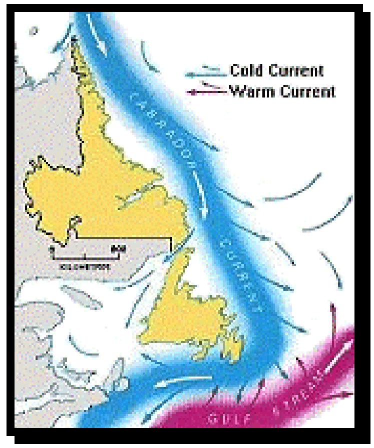
In addition to complying with all federal regulations, launch sites in the continental United States, within the boundary of a State, would need to comply with applicable state laws regarding their proposed facilities and operations. Further analysis would be done during review of specific launch application technical data and site-specific environmental documentation.

3.3.1 Local Climate/Atmosphere

Climatological and meteorological information is required in the analysis of the environmental effects of launch operations. This information supports predictions of the general dispersion of atmospheric pollutants that may be released by vehicles licensed for launches as a result of the preferred alternative. Thus, this section examines generalized local climatic and atmospheric environments. However, the scope of this PEIS does not examine the specific, local environments of launch activities. Analysis of the Clean Air Act and State Implementation Plans, including the determination as to whether the federal action is a de minimus action, would be addressed in site-specific environmental documentation.

Mid-Atlantic Coastal Environment. This climatic region is known as the humid continental warm summer climate zone. Climate is affected by the Atlantic Ocean, and the air current known as the Labrador Current (which pushes the Gulf Stream off shore) (Figure 3-1).

Figure 3-1
Labrador Current



In winter, the climate is dominated by polar continental air masses, and in summer, by tropical maritime air masses. Four distinct seasons have characteristic precipitation and temperatures. Winter is usually wet with low temperatures. Spring is also wet, although temperatures are higher. Summer is hot and humid with many thunderstorms. Autumn has slightly decreased temperatures and strong frontal systems with rain and sustained winds. The annual average precipitation is 93 cm (36.8 in), and the annual average temperature is 17°C (56°F). Winds prevail from the south with greatest speeds in February and March.

Severe weather conditions occur with hurricanes, northeasters, and thunderstorms. These result in high winds, heavy rainfalls, and reduced visibility. Hurricanes most often occur from August through October, while northeasters develop frequently in the winter. Thunderstorms are common during the summer.[50]

<u>Southeastern Atlantic Coastal Environment.</u> The climate in the southeastern U.S. coastal environment is subtropical, characterized by short mild, winters and long hot, humid summers. The average temperature is 21.7°C (71°F). Annual precipitation ranges from 114 cm (44.9 in) to 127 cm (50 in). Rainfall distribution is seasonal, with a wet season occurring from May through October. This area has the highest number of thunderstorms in the U.S., and one of the highest frequencies of occurrence in the world during the summer. Freezing conditions in this climate are rare. Close to the coast, temperatures are moderated by the Atlantic Ocean.

The humidity in this region is highly variable. Summer humidity is typically between 70 and 90 percent. During the non-summer months, the relative humidity is high in the morning (e.g., averaging 90 percent), but drops to between 55 and 65 percent by noon.

Severe weather conditions occur with hurricanes and thunderstorms. These result in high winds, heavy rainfalls, and reduced visibility. Hurricanes most often occur from August through October. Thunderstorms are common during the summer.[51]

Wind speed and direction are variable and correlate with the seasonal meteorological conditions. Winds during the summer are predominantly from the south and southeast, becoming more easterly in the fall. During the winter, winds are typically from the north and northwest. Uneven solar heating of land and water during the summer causes a sea breeze (from ocean to land) during the day and a land breeze (from land to ocean) at night. Inversions are uncommon, occurring approximately two percent of the time.[52]

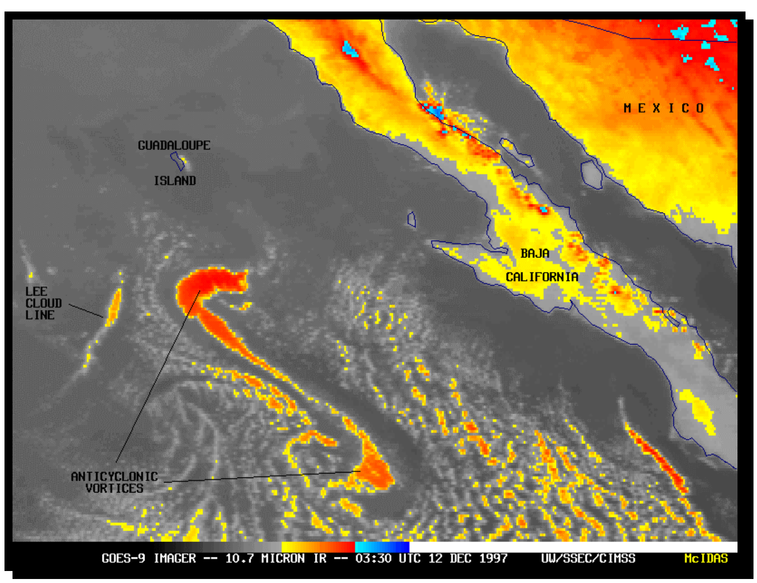
Southwestern Desert-Arid Environment. The southwestern desert arid environment is characterized by relatively mild winters with hot summers. Monthly average temperatures are 7°C (44°F) in January and 32°C (90°F) in July. Average annual rainfall is 23 cm (9 in) at higher elevations and 15 cm (6 in) at lower elevations, with about half the total occurring during July and August due to local thunderstorms.[53] Lightning strikes are a common occurrence. In 1991, for example, an area typifying this environment was subjected to up to 13 lightning strikes per square mile.[54] Most common wind directions are south and southwest, and the strongest winds occur in the late winter and spring. At higher elevations, the average annual wind speed is 10 miles per hour.

South Central California Pacific Coastal Environment. The climate in this environment type is Mediterranean, characterized by warm, dry weather from May to November and cool, wet weather from December to April. The Pacific Ocean has a moderating influence on weather patterns.

The average annual temperature is around 12.8°C (55°F), and the mean annual relative humidity is 77 percent. The average precipitation is 32.3 cm (12.7 in) per year. More than 90 percent of the region's precipitation falls between November and April. Coastal fog and low clouds are common in the morning hours, especially during the summer months when atmospheric inversion conditions intensify.

Wind directions and speeds vary with proximity to the coast, topographic characteristics, and season. Santa Ana winds, resulting from inland high pressure cells that cause warm, dry northeasterly winds to descend down the mountain slopes to the Pacific Coast, can interrupt the normal Mediterranean climate patterns for several hours to several days. (See Figure 3-2) The Santa Ana winds most commonly occur during the fall and winter months. During these periods, relative humidity in the region decreases to less than 10 percent, while temperatures increase accordingly.

Figure 3-2
Santa Ana Winds off the Western United States



The average maximum mixing height (which indicates the upper limit of the atmospheric region where pollutants and emissions tend to remain) ranges from approximately 900 m (2,950 ft) above sea level in July to 1,350 m (4,430 ft) above sea level in November. The mixing height is controlled by the location in the atmosphere of the first layer of air that is warmer than the air below. In this region, the mixing height tends to increase with winds originating from the north and west, and tends to decrease with winds from the east. Higher mixing heights facilitate dispersion of trapped air pollutants.

Subarctic Pacific Environment. The climate in this environment type is Maritime. Weather is affected by cool, humid air masses from the ocean. Long, mild winters last from November through March, with snowfalls occurring December through February. Average daily temperatures during the winter are -1°C (30°F). Average wind speeds are 5.4 meters per second (12 miles per hour). The fall months of September and October have minimal rain and snow with temperatures generally in the 4 to 10°C (40 to 50°F) range. Average wind speeds are 4.5 meters per second (10 miles per hour). The summer months are cool, humid, and windy. Precipitation occurs during half of the months and the sky cover is generally overcast. Average daily high temperatures reach 15.6°C (60°F), but vary greatly depending on the winds. The spring months of April and May are characterized by precipitation on half of the days in each month. An average snowfall during this spring season is 20 to 33 centimeters (8 to 13 inches).

Hazardous weather conditions occur with heavy fog, large snowfalls, and high winds. Heavy fog with visibility of a quarter of a mile or less usually occurs twelve times a year. The large snowfalls in December through February range from 100 to 110 centimeters (40 to 45 inches). High winds occur throughout the year. Monthly peak wind gusts range from 16 meters per second (35 miles per hour) in June to 37 meters per second (83 miles per hour) in December.[55]

Ocean or Open-ocean Environment.[x] Launch facilities may include several parts; a mobile floating launch pad which could be partially submerged for stability during the launch and an assembly, command ship from which the launch could be controlled and facilities on board to house the workers during the launch activities, and home port facilities where LV and payload can be integrated and maintenance and testing operations can be conducted. An ocean or open-ocean environment might consist of a circular area with a radius of 5 kilometers, centered at the launch pad. The ocean or open-ocean environment would exist at certain points in time, for example when the launch pad is in a pre-approved geographical region, when the launch pad is in the semi-submerged configuration, and from the time the assembly command ship pulls up to the launch pad to start checkout until the time the assembly command ship pulls away from the launch pad after launch activities are complete.[56]

The typical climate of an island in the equatorial zone near where ocean or open-ocean launches might take place has a temperature range between 18.9°C (66°F) to 33.9°C (93°F). Annual rainfall is around 63.2 cm (24.9 in), and the annual number of days with rainfall is approximately 47.3 days. An approximate number of days per year with thunderstorms is 0.6 days. The annual percent frequency of wind speed greater than or equal to 8.8 m/sec (17 knots) is 1.7 percent of the time, with no winds reported over 14.1 m/sec (28 knots).

Ocean currents, winds, and weather patterns are closely linked, especially along the equator in the Pacific. Surface waters cooler than 28°C normally dominate the equatorial ocean and the Pacific Coast of South America.[57] The equatorial Pacific Ocean is a complex environment in terms of its oceanographic biogeochemical processes. This unique ecosystem is characterized by complex ocean-atmosphere interactions and a physically dynamic oceanic circulation pattern.[58] An important process affecting conditions in this region of the Pacific Ocean is the El Niño phenomenon; every three to five years, this cyclical pattern of ocean and atmospheric conditions changes dramatically.[59] (See Figure 3-3

[x] The sea environment described in this PEIS may most closely resemble that of an equatorial Pacific environment.

and 3-4) Warm waters occur along the equator and west coast of South America, oceanic nutrient concentrations increase, wind patterns shift, and the effects are felt over much of the Earth. Conversely, tropical instability waves (westward propagating waves along the equator) produce effects lowering sea surface temperatures and increasing nutrient concentrations.

Figure 3-3
El Nino Process

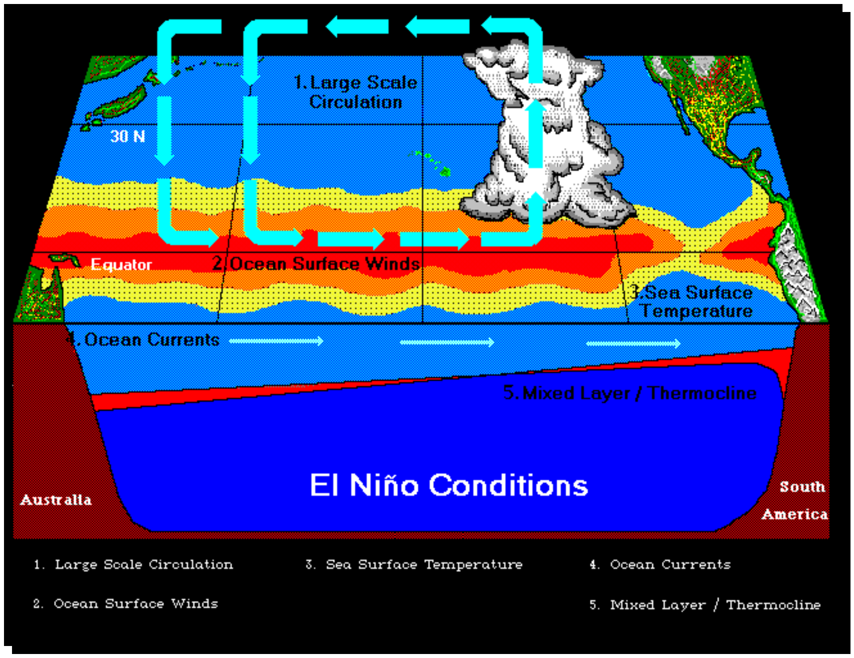
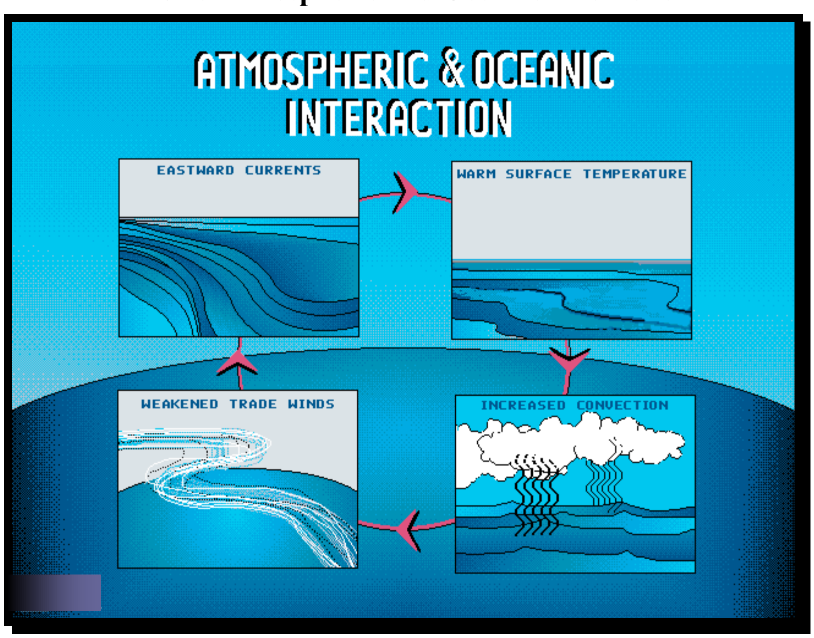


Figure 3-4
El Nino Atmospheric and Oceanic Interaction



3.3.2 Regional Land Resources

No land resources would be involved in LV launches from an ocean or open ocean-based launch platform. Generic characteristics of the local land resources of the other environments are detailed below.

Mid-Atlantic Coastal Environment. Topography in the Mid-Atlantic coastal region is generally flat with no extreme deviations. There are numerous inlets, marshes, bays, creeks, and tidal estuaries. The region is characterized by frequent flooding from storms. The area is located within the Atlantic Coastal Plain physiographic province. Soils are generally very level, acidic, have low natural fertility, and are high in organic content which results in a highly leached condition, (i.e., soluble particles have been removed by the percolation of water).[60]

Southeastern Atlantic Coastal Environment. Topography in this region tends to be very flat. Barrier islands (similar to an offshore bar except they have multiple ridges), areas of vegetation, and swampy terraces extending towards the lagoon, are common along the Atlantic coast. Native soils tend to be highly permeable, fine-grained sediments typical of beach and dune deposits.[61] There is considerable heterogeneity in soil conditions; two major distinct groups are saline soils and non-saline soils.[62]

Southwestern Desert-Arid Environment. Topography in this region includes both desert and mountainous terrain. There are north-south trending mountain ranges with intervening valleys. The region has a history of faulting and volcanic activity. The geology includes sedimentary, granitic and volcanic rocks.[63]

There are many soil types within this environment, including rock outcrops. With the exception of Marconi soil and some clay, soils generally are well drained, and are composed of gravels, sands, and sandy and loamy silts and clays. Soils are coarse-grained near the mountain fronts and fine-grained in the valleys. They have a high salinity in the valleys. Organic matter, or matter derived from living organisms, in these soils is low, generally below one percent. There are sand dunes scattered throughout the area creating a potential for blowing soil from wind erosion.

South Central Pacific Coastal Environment. Topography in this region varies greatly, particularly close to the coast, which may range from very rocky, steep cliffs to gradual slopes and flats. Intermittent drainages (e.g., major or minor canyons) are common. East-west chains of islands - mountainous outcrops in the Pacific Ocean - can be found off the coast.

This environment contains a complex and varied geology that gives rise to an equally complex pattern of topography and soils. Oil and gas are the dominant geologic resources, and have been extracted from both onshore wells and offshore platforms. The entire south central Pacific coast is seismically active.

Subarctic Pacific Environment. Topography in this region varies greatly, ranging from mountains and hills to flat, low lying areas. These areas are characterized by seismic activity, flooding, and landslides. Soils in this type of environment vary, but are usually moist due to the precipitation. In areas where the large amounts of precipitation result in water tables at or near the surface, the soils have a high organic matter content, which produces a relatively high cation exchange capacity (sum of exchangable cations that a soil or other material can absorb at a specific pH). This property allows soils to offer resistance and be strongly buffered against changes in pH.[64]

3.3.3 Regional Water Resources

Surface and groundwater resources that may exist in the vicinity of proposed or currently licensed launch sites are discussed in the following subsections.

Mid-Atlantic Coastal Environment. Surface waters in this environment are saline to brackish (having salinity values ranging from approximately 0.50 to 17.0 parts per thousand), and tidally influenced due to their coastal location. Most water-bearing groundwater formations consist of sedimentary units, ranging in age from Cretaceous to Quaternary. Major aquifers (subsurface zones that yield important amounts of water to wells) are recharged by surface waters or infiltration of precipitation. Groundwater quality is generally good, although moderately hard, with little or no fluoride present. Within the tidal areas, there is brackish water due to saltwater intrusion. There may be localized iron (from saltwater intrusion) and nitrate (from fertilizers, precipitation, and landfills) in shallow aquifers. The sea level is expected to rise due to the combined effects of land subsidence and fluctuations in global temperatures. A common floodplain (smooth valley floor adjacent to and formed by flowing rivers, which are subject to overflow) protection measure in this region is the construction of seawalls to protect the shoreline from erosion. Damage from tidal floods depends on the topography, the rate of rise of floodwater, depth and duration of flooding, exposure to wave action, and the extent of development in the floodplain.[65]

Southeastern Atlantic Coastal Environment. Typical surface water bodies are a mix of shallow estuarine lagoons and major inland water bodies (e.g., large lagoons and rivers). These surface water bodies are used for a range of activities, including recreation, propagation, and management of fish and wildlife, and may be designated as aquatic preserves, Estuaries of National Significance, and/or Outstanding Florida Waters.

Surficial, unconfined aquifer systems exist in upper unconsolidated sediments. These surficial aquifer systems are recharged by precipitation, and can produce good quality water but are very susceptible to contamination. The Floridan aquifer is located beneath confining units below surficial aquifer systems and is the primary drinking water source for the majority of Florida residents. However, in the mid-southeastern coastal region of the state the Floridan is highly mineralized and is generally unsuitable for domestic, industrial, or agricultural use.[66]

Southwestern Desert-Arid Environment. Most desert environments have scarce amounts of surface water except selected areas where springs are common. Springs are the only source of perennial surface water. Ephemeral surface water is derived from nearby mountains and contributes to surface dirt tanks and transient ponds in the water courses. Heavy rain on the packed desert floor runs off rapidly or infiltrates into the dry soil. In floodplain areas, the water runs off less rapidly, but still does not stand or pond. On flats, rainwater may stand and cause flooding.[67]

Aquifer systems underlying the region have varying depths, water levels and areas of confinement. Recharge to aquifers occurs in areas immediately adjacent to major mountain ranges. Some aquifer recharge occurs from storm-water discharge through canyons and arroyos.

South Central Pacific Coastal Environment. The Western Santa Ynez Mountains receive an average annual precipitation of about 41 cm (16 in) per year, with a runoff rate of two to three inches per year. Local drainages may discharge directly into the Pacific Ocean. The flow rates associated with these drainages can be highly variable; many channel water only during storm events. Intense storm episodes produce high intermittent yields due to the relatively steep topography of the area. Some drainages in the area may be spring fed, although ground percolation frequently traps the water flow before it reaches the ocean.

Streams tend to be high in hardness, alkalinity, and specific conductance, but low in acidity, chemical oxidation demand, and total organic carbon. The alkalinity refers to the streams having excess hydroxide ions in solution. These streams also in general have high levels of certain elements such as calcium, iron, magnesium, and sodium.

The underlying rock formation in this region supports a minimal amount of groundwater in the fracture zones. Lower members of the formation contain greater amounts of water than the upper levels.

Subarctic Environment. The subarctic environment typically has riverine, estuarine, and marine systems. The general types of water environments are freshwater streams and lakes, and salt-water influenced lagoons.[68]

3.3.4 Regional Biological Resources

The following subsections consider local flora and fauna near existing and proposed launch sites.

Mid-Atlantic Coastal Environment. Wetlands in this region are classified as tidal or non-tidal. The three predominant wetland systems are marine wetlands, estuarine wetlands (wetlands that are continuously submerged or are by turns exposed and flooded by tides), and palustrine wetlands (these wetlands can be nontidal and not vegetated, or have small amounts of woody vegetation). All marine and estuarine wetlands, as well as some palustrine wetlands, are considered tidal wetlands. Non-tidal wetlands can include riverine, lacustrine, and palustrine wetlands. Lacustrine wetlands are situated in topographic depressions surrounding lakes or pooled rivers.

Tidal wetlands include vegetated wetlands such as swamps, marshes, and bogs, as well as non-vegetated wetlands such as beaches and tidal flats. Vegetated tidal wetlands provide wildlife habitat values such as nesting grounds for many species of migratory waterfowl, water birds, and songbirds. These wetlands provide nourishment for oysters, clams, scallops, crab larvae, and newborn fish by providing detritus. The vegetation can absorb wave energy, filter water, and prevent erosion. Typical vegetation includes the saltmarsh cordgrass, salt meadow cordgrass, cattail marshes, black needlerush, saltwort, and reedgrass.[69]

Non-tidal wetlands support vegetation adapted for life in saturated soil conditions (hydrophytic vegetation). These wetlands also provide wildlife habitat, attenuate floodwater, and provide erosion control. Non-tidal wetlands are classified according to their vegetation. Forested wetlands include swamps dominated by trees over 20 feet in height, such as the red maple, river birch, and ashes. Scrub shrub wetlands include tree shrub swamps dominated by trees less than 20 feet in height, such as the alder, buttonwood, and spicebush. Emergent wetlands are marshes with common vegetation being cattails, sedges, and rushes. Aquatic bed wetlands are dominated by plants that grow on or below the surface of the water, such as spatterdock and pickerelweed.[70]

The Mid-Atlantic coastal region contains barrier islands, which are often considered wetland resources. They are narrow land forms consisting of unconsolidated and shifting sand. These islands contain coastal primary sand dunes and swales, which serve as barriers against flooding and erosion caused by coastal storms. The dunes are dominated by northern bayberry, wax myrtle, groundsel-tree, and reeds. Species in the dune system include seabeach orach, common saltwort, sea rocket, and seaside goldenrod. Where there is intense wave action, phytoplankton, macroalgae, and eelgrass are prevalent.

In addition to the dunes, barrier islands contain beaches, maritime forests, and marshes. The maritime forests typically have loblolly pine, cherry trees, northern bayberry, and wax myrtle. Thickets also have clusters of northern bayberry and wax myrtle, as well as dense poison ivy and greenbriar.[71] Barrier island marshes are dominated by saltmarsh cordgrass.[72] The marshes contain many species of marine and bird life, as well as a variety of invertebrates, such as grasshoppers and planthoppers. There are a number of parasitic flies, wasps, spiders, and mosquitoes.[73] Calico crabs, sand shrimp, moon jelly, and coffee bean snails are common in this environment.

Fish species in this Mid-Atlantic coastal region vary depending on changes in inlets and channels, salinity, tide, and temperature changes. Common species include the northern pipefish and the bay anchovy. Others are the sandbar shark, smooth dogfish, spot, and flounder.[74] Amphibians and reptiles characteristic to this region are the fowler's toad, green tree frog, black rat snake, box turtle, and diamondback terrapin.

Shorebirds include the sanderling, red knot, dunlin, willet, terns, and gulls. Sparrows, red-winged blackbirds, fish crows and mourning doves are also common. Mockingbirds, robins and starlings are prevalent throughout the year.

Mammals found in the Mid-Atlantic coastal region include the white-tailed deer, opossum, raccoon, red fox, meadow vole, and grey squirrel. Shrews, moles, rabbits, and bats are also common. The waters are also inhabited by whales, dolphins, and porpoises.[75]

<u>Southeastern Atlantic Coastal Environment.</u> Ecological resources in the southeastern Atlantic coastal area are influenced by the Atlantic Ocean on the east. Vegetation communities and related wildlife habitats are representative of barrier island and coastal resources. Major communities include beach, coastal strand and dunes, coastal scrub, lagoons, brackish marsh, coral reefs, and freshwater systems in the forms of canals and borrow pits. Coastal hammocks and pine flatwoods may also be found. In terms of aquatic biota, the region is a transition between temperate and subtropical forms.[76]

Wetland types found in this region include freshwater ponds and canals, brackish impoundments, tidal lagoons, bays, rivers, vegetated marshes, and mangrove swamps. These wetlands provide resources for a vast assemblage of marine organisms, waterfowl, and terrestrial wildlife. For example, fish living in the marsh habitat include the gar, killifish, mosquito fish, and top minnow; amphibians include the leopard frog; and reptiles include the box turtle, various species of snakes, and alligators. Mammals living in the marsh habitat include different species of rats and mice, raccoons, river otters, muskrats, and deer. Wetland resources in this area are managed by controlling water levels in impoundments, stocking fish in freshwater bodies, and legally protecting many wildlife species as well as the wetland habitat itself.[77]

This region is one of the most biologically diverse coastal ecosystems in the continental U.S., containing a large number of federally protected species.[78]

Typical plant communities include coastal dune, coastal strand, freshwater marsh, freshwater swamp, and developed areas dominated by terrestrial grasses and weeds. Sea grasses are an important component of the aquatic environment.

There is a wide variety of mammals, birds and reptiles in this environment type. The range of mammals includes several species of whales, as well as manatees. Various types of warblers, jays, falcons, woodpeckers, and eagles have habitats in the area as well. Reptiles include the American alligator, as well as numerous species of turtles and snakes.[79]

Southwestern Desert-Arid Environment. From a biogeographic perspective, the southwestern desert area encompasses three major vegetation types. In order of dominance,[80] these are semidesert grassland, plains-mesa sand scrub, and desert scrub. In species composition, these three vegetation types correspond to the desert scrub biotic community and the semidesert grassland biotic community.[81] Grassland habitat merges with desert scrub, creating a complex landscape mosaic. Major vegetation in the desert scrub area includes a combination of woody and herbaceous shrubs such as the creosote bush, shadscale, winterfat, and white bursage. Plains-mesa sand scrub separates semidesert grassland and desert scrub vegetation. The desert scrub vegetation is divided into broadleaf evergreen and broadleaf deciduous types. Flora in this region include sunflowers and buckwheats. There are no wetland types in this environment, however, springs support wetland type vegetation, such as cattail, sedges, and rushes.

The majority of the arthropod species are insects such as ants, termites, and darkling beetles. Common birds are the raven, red-tailed hawk, scrub jay, and black-throated sparrow. Other species that can be found in this region include coyotes, bobcats, speckled rattlesnakes, desert woodrat, and mule deer.[82]

South Central Pacific Coastal Environment. The south central Pacific coastal environment represents a transition zone between the cool, moist conditions of northern California and the semi-desert conditions of southern California. Consequently, many plant species, as well as plant communities, reach their northern and southern limits in this area. Plant communities of particular interest include tanbark oak forest, bishop pine forest, Burton Mesa chaparral, coastal dune scrub, and a variety of wetland types.

Typical vegetation communities include central coastal scrub, coastal sage scrub, coastal dune scrub, grassland, and chaparral. These communities are adapted to periodic burning, and many plant species re-sprout readily after fire. Where disturbances are frequent and intense, ruderal and exotic species replace the native vegetation. Many local canyons support riparian woodlands.

Many species commonly found in coastal sage scrub vegetation environments include deer, badger, coyote, desert cottontail rabbit, turkey, vulture, red-tailed hawk, American kestrel, white-tailed kite, and northern harrier. Other bird species that may be found include raptors, loggerhead shrike, rufous-sided towhee, rufous-crowned sparrows, Bell's sage sparrow, and burrowing owls. Turtles, pelicans, lizards, frogs, sea otters, and harbor seals also have habitats in this area.[83]

The coastline of this region is occupied by several species of seabirds, marine animals , and other species of interest. Harbor seals, protected under the Marine Mammal Protection Act, use the beaches as haulout and pupping areas. Southern sea otters also feed in the offshore kelp beds and occasionally come ashore. Peregrine falcons nest on the rocky cliffs. Western gulls, brown pelicans, pigeon guillemots, pelagic cormorants, rhinoceros auklets, black oystercatchers, and Brandt's cormorants use the rocky outcrops for roosting or nesting purposes.

Subarctic Environment. The major plant life associated with this region includes forests, shrublands, meadows, and wetlands. A common type of forest is the spruce forest. The shrublands include the closed alder and mixed alder-willow. Typical types of meadow are the low shrub-forb, the willow-hairgrass-mixed forb, the mixed dwarf shrub-graminoid, and lupine meadow.

There are typically non-vegetated and vegetated wetlands. Permanently flooded wetlands have no vegetation or only rooted vascular aquatic vegetation. Vegetated wetlands include semi-permanently flooded areas, saturated emergent wetlands, and marshes. Semi-permanently flooded areas have sandy substrates with less than 30 percent vegetated cover. Saturated emergent meadow wetlands usually have mineral soils with only sedge-forb and sedge-forb moss. Emergent sedge marshes exhibit standing water throughout the growing season. Other vegetated wetlands include saturated tall shrub thickets and dwarf shrub moss with 70 percent or greater coverage of broad-leaved deciduous shrubs.

The habitats in this environment are generally not high quality due to the harsh conditions. Typical bird species in the water habitats include loons, grebes, dabbling and harlequin ducks, gulls, and kingfishers. In the forests, species include varied thrushes, goshawks, golden-crowned kinglets, and boreal chickadees. Wetland bird species include common snipe, mew gulls, terns, and sparrows. Other common bird species are mallards, gulls, ravens, and falcons.[84]

Mammals in this environment include the little brown bat, red squirrel, tundra vole, red fox, black-tailed deer, brown bear, beaver, snowshoe hare, mountain goat, short-tailed weasel, and muskrat. There are various freshwater and anadromous fish.

Marine birds include terns, puffins, gulls, and cormorants. Common marine mammals include cetaceans, harbor seals, sea otters, and whales. Marine fish include flounder, sole, pollock, skate, cod, and halibut. Other common marine organisms include crabs, scallops, octopus, shrimp, clams, jellyfish, sea urchins and mussels.[85]

Ocean or Open-ocean Environment. The most prevalent biologic organism in the deep ocean environment are tiny phytoplankton. Phytoplankton represent most of the ocean's organic material and are produced in open-ocean waters. Most major fisheries, on the other hand, are located in coastal waters, particularly in upwelling areas. Micro-phytoplankton productivity is an important measure of the oceans' food supplies. Also called primary productivity, these rates largely regulate fishery cycles and may be significant in the global carbon cycle. In general, the equatorial ocean zone is characterized by a large number of species, large biomass, and substantial east-west variability.

Open-ocean food webs are typically long, involving many energy transfers. Only the smallest phytoplankton grow in the nutrient-poor open-ocean waters, and these in turn are consumed by very small herbivores. These tiny herbivore animals are preyed on by animals in the one-millimeter size range, and they, in turn, by secondary carnivores that are about one centimeter long. In many cases, one or two larger invertebrate animals or fishes form additional links in the open-ocean food chain before it reaches a carnivore, such as mackerel or tuna.[86]

Examples of fish and marine animals found in the equatorial open-ocean environment include mackerel, anchovies, sardines, herring, menhaden, angler fish, sharks, squid, whales, dolphins, and porpoises. Seabirds may also be found in the open-ocean environment, and include auks, albatrosses, petrels, and gannets.[87]

Frequent upwelling of cold, nutrient-rich water at the equatorial divergence supports a highly productive phytoplankton community. However, the equatorial Pacific Ocean is characterized by high nutrient concentrations that are not accompanied by high phytoplanktonic biomass and primary productivity values. Processes such as grazing control, iron limitation and lack of coastal bloom-forming diatoms have been invoked to explain this paradoxical high-nutrient and low-chlorophyll condition.

3.3.5 Marine Species in Atlantic and Pacific Oceans

The Pacific Ocean is the largest ocean in the world followed by the Atlantic Ocean. Island chains are most numerous in the Pacific and volcanic activity around the margins is pronounced. In contrast, the Atlantic is relatively narrow and is bordered by large marginal seas such as the Gulf of Mexico. Its average depth is less than the Pacific Ocean.[88]

The western Pacific is monsoonal (a rainy season that occurs during the summer months), when moisture-laden winds blow from the ocean over the land. Natural resources include oil and gas fields, polymetallic nodules, sand and gravel aggregates, placer deposits, and fish. The West Coast is also host to a wide variety of species, including marine animals; seabirds; fish, shellfish, and kelp; and intertidal organisms. Marine animals are predominanatly pinnipeds (carnivorous, flippered, mammals of the family Otariidae, Phocidae, or Odobenidae) and cetaceans (whales, dolphins, or porpoises).[89] Endangered marine species include the dugong, sea lion, sea otter, seals, turtles, and whales.

On the East Coast, depths range from 0 to roughly 4,000 meters (2.5 miles) in the Atlantic Ocean. Organisms found along the East Coast include phytoplankton and zooplankton, marine macroinvertebrates (such as crabs, shrimp, and squid), fish, sea turtles, and marine mammals. Endangered marine species include the manatees, seals, sea lions, turtles, and whales. Specific areas of the continental shelf waters off the northeastern U.S. coast consistently show high-density utilization by several cetacean species. For example, the western margin of the Gulf of Maine is used most intensively as cetacean habitat. In general, habitat use by cetaceans is highest in spring and summer, and lowest in fall and winter. The Atlantic coastal and offshore areas also contribute significantly to the nation's finfish and shellfish harvests.[90]

3.3.6 Threatened and Endangered Species

Site-specific environmental documentation will identify and, if appropriate, analyze potential impacts to threatened and endangered species in the vicinity of the launch site or flight path. License applicants will be required to comply with the Endangered Species Act.

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4. POTENTIAL ACCIDENT SCENARIOS

In this chapter, background is presented on the safety criteria used by the FAA in licensing decisions. The operating history of the U.S. LV industry is also examined. Finally, two generic types of accidents are described. These accidents form the basis for the evaluation of environmental consequences from accidents in Section 5.

4.1 FAA Safety Considerations in Licensing Decisions

The FAA Licensing and Safety Division is responsible for regulating and licensing launch activities for safety. The FAA's responsibilities include reviewing license applications for safety adequacy and developing public safety requirements and standards. A Safety Review is a critical part of the licensing process and ensures that license applicants will comply with established requirements and procedures.

Each federal launch range has safety requirements and procedures (e.g., Eastern and Western Range 127-1, Wallops Flight Facility Range Safety Manual). U.S. licensed launch site operators are subject to the FAA's licensing and safety regulations. Licensed launch sites co-located with federal launch ranges are subject to the FAA's licensing and safety criteria; however, these facilities may adopt existing federal range requirements if they are found to meet the FAA regulations.

Although the risk to the public and property can never be completely eliminated, safety systems and procedures such as real-time tracking, flight safety systems, autonomous, on-board, redundant safety systems, and flight path destruct lines are employed to ensure the risks to the public and property are minimized to acceptable levels. Safety destruct lines are chosen to prevent debris from impacting on or near populated areas.

4.2 United States Historical Launch Success Rate

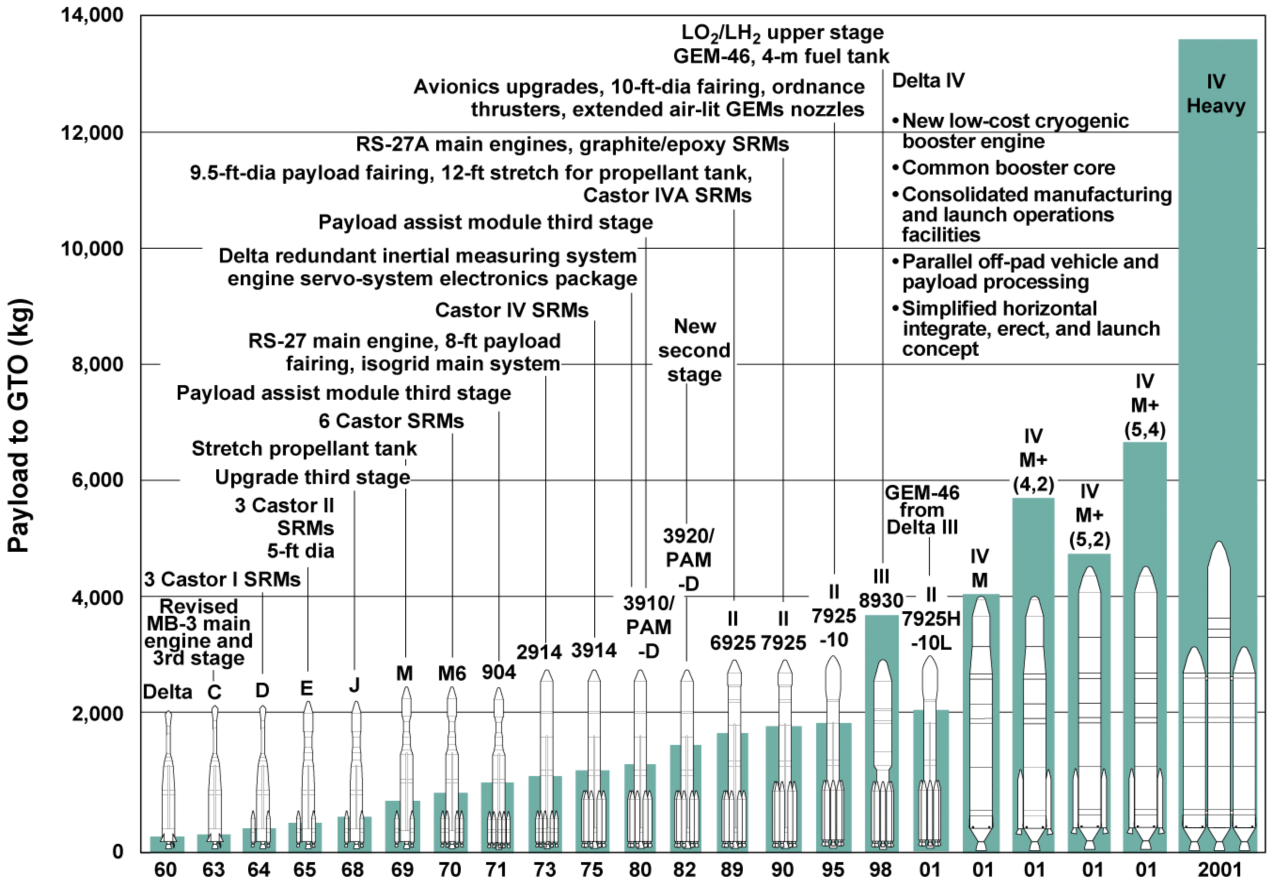
The United States commercial launch industry is based primarily on technology developed for the government and more specifically for military applications. Thus, an extensive government procurement system, including verifying performance-based specifications from the design to prototype and subsequent manufacturing phases, has already been used for quality assurance and quality control prior to the use of vehicles for commercial markets. As new or significantly modified launch vehicles are introduced to the market they may initially experience a higher failure rate than mature launch vehicles. The Atlas has had 232 successful launches in 267 attempts (86.9% success rate) in the 1958 to 1994 time period. (See Figure 4-1)

Figure 4-1
Atlas IIA Centaur Vehicle (1996)

Similarly, Delta LVs have been successful in 263 of 278 launches (94.6% success rate) from 1960 to May 2000. (See Figure 4-2 and 4-3)

Figure 4-2
Delta III Vehicle

Figure 4-3
Delta Vehicle Series[y]



[y] Graphic provided by the Boeing Company October 29, 1999.

The Titan, a high payload capacity vehicle that has only been used once for commercial applications, has an overall 93.4% success rate from 1964 to 1994. (See Figure 4-4) Most of the failed launches of these LVs occurred during early vehicle research and development (e.g., approximately the first ten years), and the trend has been for increasingly successful launch rates over time.

Figure 4-4
Titan 3 Vehicle (1992)

The newer developments in the LV industry have been smaller vehicles that are more cost-effective for placing satellites into LEO. These vehicles have not been used for government-supported launches as have the LVs with larger payload capacity discussed above. Thus, these LVs, which incorporate novel applications of existing technology, may initially experience some launch anomalies and accidents until the vehicle program becomes more mature. The reusable LV approach is also unique, in that it combines operational characteristics of RVs and ELVs.

4.3 Accident on Launch Pad

The scope of this PEIS begins with ignition of an LV's propulsion system. For a land- or ocean-based LV, this takes place on a launch pad or platform. An LV's flight termination system is armed prior to launch, and can be fired automatically, or manually any time after the system is armed. The flight safety officer would withhold destruct action, regardless of system failure, until there is a real danger to public safety or property. This may allow a full mission duration to burnout. Launch site personnel are sheltered at a safe distance, as determined by Range Safety personnel, from the launch pad and are therefore protected from an on-pad explosion. In addition, the FAA has proposed as of October 25, 2000, the following definition of flight hazard area: regions of land, sea, and air that are exposed to the potential adverse effects of planned and unplanned launch vehicle flight events and that must be monitored, controlled, or evacuated in order to ensure public safety. Within the first 10 seconds, the consequences of an on-pad explosion accident could impact the local environments described above in Section 3.3. Such consequences are detailed below in Section 5.3. For an air-based launch platform, an accident occurring in the initial 10 seconds after release from the carrier aircraft could likely expose the aircraft to fragments.

4.4 Accident during Vehicle Ascent

This accident scenario will be discussed in three subsections: (1) ELVs using flight safety systems (FSS) with command in-flight termination capability and range safety systems (currently most existing LVs use these technologies) or with thrust termination (e.g., as is used by an autonomous system that is launched from the water); (2) impact ranges for sounding rockets; and (3) alternate safety systems for proposed reusable LVs.

All existing and proposed launch vehicle configurations use composite materials for parts of the vehicle structure and some propellant tanks would be comprised totally of composites or FRP (fiber reinforced plastics). The fiber can be glass, carbon, or aramide (an organic polycyclic material) filament, mat, or tape. RFP composites provide high tensile strength, low density, low weight material for structural components and tanks. The consequences and possible impacts of an accident involving the potential burning and partial breakup of composite vehicle structures cannot be adequately assessed at this time because final materials and fabrication processes have not yet been determined. Further analysis would be done during review of specific launch application technical data and site-specific environmental documentation.

An anomaly that occurs after the LV leaves the launch pad, (or in the case of air-based launches, the aircraft) would result in the use/activation of a flight safety system. Examples of possible anomalies include when the LV does not stay on trajectory, or when the LV experiences system failure (electrical, propulsion, guidance, etc.). The goal of flight safety is to contain the flight of the vehicle and prevent an impact which might endanger human life or cause damage to property.

The FAA defines a flight safety system (FSS) as a system that provides a means of preventing a launch vehicle and its hazards, including any payload hazards, from reaching any populated or other protected area in the event of a launch vehicle failure. An FSS, unless otherwise approved in the course of the licensing process, consists of an onboard vehicle flight termination system (FTS) and command control system. An FSS also includes the functions of any personnel who operate FSS hardware and software.

Federal launch ranges typically require an FTS on guided launch vehicles that have a capability to violate established safety criteria under powered flight, in order to protect the public and range personnel. For ELVs equipped with a command flight termination capability, if a vehicle's IIP crosses a destruct line, the FTS is activated to destroy the vehicle. The reliability of the FSS plays more of a role than the reliability of the launch vehicle in achieving safety. The FAA seeks to maintain the same high level of safety that the federal ranges have achieved. At the same time, the FAA recognizes that more than one method exists by which to protect the public and achieve the requisite levels of safety.

An autonomous system uses a computer to evaluate vehicle status as well as vehicle performance to determine if a flight termination command is required. The U.S. standards require an FTS to destroy a vehicle, not just terminate the motor thrust as is accomplished by a thrust termination system. An U.S. FTS is designed to terminate the thrust of the vehicle and to disperse the propellants with minimal explosive effect.

ELVs. Real-time flight safety control systems are utilized for ELVs that reliably perform the following functions: (1) continually monitor the launch vehicle performance and determine whether the vehicle is behaving normally or failing; (2) predict (in real-time) where the vehicle or pieces of the vehicle would impact in case of failure and if flight termination action is taken; (3) determine if there is a need to delay or abort the launch or stop the flight of the vehicle, based on a comparison of predetermined criteria with the current vehicle status; and (4) if necessary to protect the public, send a command to abort the mission either by vehicle destruct or engine shutdown (e.g., using a thrust termination system (TTS)).

An FSS is comprised of several components, the most significant of which, for purposes of discussing accident scenarios, is the FTS. The FTS provides a means of destroying a launch vehicle in the event it deviates from a planned course. Most ELVs carry an FTS to destroy them. Some flight safety systems, however, rely on a TTS instead. Rather than destroying the vehicle, a TTS shuts down the launch vehicle's engines, and halts its thrust so that it does not continue on its previous path. RLVs are expected to employ different types of flight safety systems, as discussed in the second subsection.

The purpose of the flight safety system is to contain the flight of an LV and to prevent impact between an LV or its components and people and property. To that end, prior to launch, a launch operator or launch site would calculate what are commonly referred to as destruct lines. These are lines that show when a vehicle's flight should be terminated so that debris does not reach the public. If telemetry or on-board systems show a launch vehicle heading outside of the destruct lines, it may be destroyed with an FTS or its thrust terminated with a TTS. Observation, data collection, and calculation constitute the necessary steps in determining whether to terminate the vehicle's flight. Early in flight, visual observation and real-time telemetry measurements provide a means of monitoring the performance of the LV. Radar tracks the position and velocity of the vehicle. An instantaneous impact point (IIP) may be calculated using the velocity and position of the LV. An IIP is calculated as a moving point on the Earth, and it shows where a launch vehicle (or its pieces) would land were the vehicle to stop moving. For ELVs equipped with an FSS with an FTS command flight termination capability, if a vehicle's IIP crosses a destruct line, the FTS is activated to destroy the vehicle. This produces a liquid propellant tank rupture. Depending on the mixture of liquid propellant used and the altitude at which the flight is terminated, propellants would most likely be instantly vaporized. Flights terminated at lower altitudes might produce very limited pooling of liquid fuel on the ground or water surface being overflown. In addition to vaporization in the atmosphere, any such pools would also quickly evaporate. Unspent solid rocket motors and other debris would land at or near the IIP. If flight is terminated when the solid rocket motors are already ignited, their integrity is destroyed. Although propellant pieces might continue to burn until impact, most solid propellants do not continue burning when the propellant grain is broken and no longer under pressure. Vehicle destruction is designed so that impacting pieces land within an established area (the area calculated along the trajectory of flight within which debris is expected to fall).

For launch of an ELV over water, the consequences of an accident at this point in the flight profile would be limited to the atmosphere and the oceans. These consequences are discussed in Section 5.

In the case of an LV using a TTS as part of its flight safety system, the engines are shutdown but the liquid propellant tanks and SRMs are not ruptured. TTS systems may be used for both ocean and land-launched ELVs. The consequences of an accident at this point in the flight profile would also be limited to the atmosphere and the oceans. These consequences are discussed in Section 5.

Under these accident scenarios, the activation (either by autonomous or by mission controlled transmissions) of the flight safety systems (and in-flight vehicle termination or TTS) serves to minimize the potential safety and environmental consequences. Prior to issuing a launch license, the FAA reviews in detail the location of the launch, the functioning of the flight safety systems, and the license applicant's procedures to ensure activation of flight termination or TTS when needed. Thus, the license application review conducted by the FAA has the effect of minimizing the potential for consequences of accidents during LV ascent.

Unguided Suborbital Launch Vehicles (including Sounding Rockets). These LVs are frequently used to conduct scientific experiments by lifting payloads to altitudes as high as 1,500 km. Sounding rockets do not deliver payloads into orbit but rather return to Earth after a rapid ascent. The first stage of a sounding rocket, when spent, lands between 0.3 and 1.5 km from the launch pad with an impact weight in the 270- to 800-kg range.[91] Small weather and test spent rockets (impact weight of 7 to 9 kg) land between 2.8 and 8.8 km from the launch pad. Thus, for the nominal launch, safety is achieved by wind weighting, clearing an area around the launch pad, assessing the risk of nominal stage impact, surveillance, clearance and proper notifications. Multiple stage sounding rockets, medium-range and final-stage spent rockets have impact ranges up to hundreds of kilometers.

Reusable Vehicles. Reusable vehicles are not designed to jettison spent stages into an ocean, but instead return to a fixed location on the ground within a restricted use landing area. Existing proposals describe launch over land. Such a vehicle would undergo extensive safety review prior to and during the FAA license application process.

By way of example, key features of one proposed reusable vehicle are:

- redundant avionics,
- redundant triggering system for "soft" landing of components using parachutes and air bags,
- "engine-out" capability to land under guidance in the event of an engine shut-down,
- use of emergency diversion locations within undeveloped and restricted access land,
- coordination with the FAA commercial use airspace,
- precise de-orbit burn by using global positioning system and orbital maneuvering system engines, and
- use of attitude control jets to make trajectory corrections during guided re-entry.

Although the items listed above would be incorporated into the reusable LV design, as currently proposed such an LV would not necessarily be equipped with a traditional flight safety system with in-flight termination capability. Thus, impacts of an accident during ascent could include the possibility of uncontrolled landing (assuming multiple failures of redundant systems).

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5. ENVIRONMENTAL IMPACTS AND CONSEQUENCES OF THE PREFERRED ALTERNATIVE

Environmental impacts to the atmosphere associated with launching LVs are addressed in the first section. Section 5.2 assesses the noise impacts experienced by receptor type (i.e., human, wildlife, structures). In Section 5.3, other potential environmental impacts are addressed including the probability assessment of marine animal strikes. The potential impacts are assessed using the six environment types and information on marine species in the oceans previously described in Section 3.3. Socioeconomic impacts are described in Section 5.4, and environmental justice impacts are reviewed in Section 5.5.

5.1. Potential Atmospheric Impacts

In this section, atmospheric impacts are assessed beginning at ground level with consideration of tropospheric effects (i.e., total atmospheric load from the ground cloud near the launch site and acid rain). Stratospheric effects, including global warming, ozone depletion, and acid rain, are detailed in subsection 5.1.2. No mesospheric effects have been identified (subsection 5.1.3). The potential for changes in ionosphere electron concentrations is assessed in subsection 5.1.4. Consideration of local potential impacts from a ground cloud near a launch site is found in Section 5.3.1.

5.1.1. Troposphere

The main potential impacts to the troposphere may result from the ground cloud formed from the ignition of rocket motors and the resulting launch of the LV. Other potential impacts to the troposphere could result from accidents on the launch pad or during flight.

Ground Cloud Near Launch Site. A ground cloud forms within the first 10-12 seconds of an LV launch. It is composed of a complex mixture of gases, dissolved and particulate exhaust products, water used for fire and sound suppression, and materials ablated from the physical surfaces on and around the launch pad. Table 5-1 shows the major exhaust products from propellants that are currently used in spaceflight or are under development. [92, 93, 94, 95, 96, 97]

TABLE 5-1
MAIN EXHAUST PRODUCTS FROM PROPELLANT SYSTEMS

Solid	Liquid Hydrocarbon	Hypergolic	Cryogenic	Hybrid Propellant
HCl, Al_2O_3, CO, N_2 CO_2, NO_x, Cl^-, H_2O	CO_2, CO, H_2, H_2O, OH^-, NO_x	CO_2, CO, NO_x, N_2, H_2O, H_2	H_2O, H_2	CO, CO_2, H_2, H_2O, NO_x, OH^-

Of the chemical species that form during ground cloud formation, the most environmentally significant are HCl, Al_2O_3, NO_x, and CO_2. Not all of these substances are produced by all of the various propellant systems. HCl and Al_2O_3 will be discussed below. NO_x is an ozone depleting substance that is produced by all propellant systems with the exception of the cryogenics (LO_x/LH_2). Environmental effects from CO_2 occur in the stratosphere and therefore are discussed in Section 5.1.2. The other emissions are either insignificant or would not be harmful to the troposphere. CO is assumed to convert to CO_2; OH converts to water vapor and is emitted in very small quantities; and some N_2 is converted to NO_x. NO_x is an important component in acid rain and photochemical smog. Table 5.2 summarizes the emissions to the troposphere by LV payload capacity and propellant types.

TABLE 5-2
ESTIMATED EMISSIONS IN THE TROPOSPHERE PER LV LAUNCH BASED ON PAYLOAD AND PROPELLANT TYPE (KG AND TONS)

Payload Capacity	Propellant Types	HCl Load		Al_20_3 Load		CO_2 Load*		H_2O Load	
		kg	Tons	Kg	tons	kg	Tons	kg	tons
Small	Solid	6,300	6.9	11,400	12.6	13,800	15.2	8,100	8.9
Medium	LO_x-RP1/Solid	7,875	8.7	14,250	15.7	52,163	57.5	22,875	25.2
Intermediate	Solid/LO_x-RP1	10,410	11.6	18,840	20.7	68,900	75.8	30,230	33.3
	Hybrid	-	-	-	-	90,630	99.7	33,100	36.4
High	Solid/LO_x-LH_2	11,550	12.7	20,900	23.0	25,300	27.9	69,850	77.0
	LO_x-RP1**	-	-	-	-	232,750	256.6	85,000	93.7
	Solid/LO_x-RP1	26,250	28.9	47,500	52.4	173,875	191.7	76,250	84.1

*CO_2 estimate includes CO_2 formed by oxidation of CO in the exhaust plume. See Appendix A for background on assumptions and calculation of emissions.

**Emissions from hydrogen peroxide propelled launch vehicles are expected to be similar to emissions from LO_x-RP1 propelled vehicles.

Models, such as the Rocket Exhaust Effluent Diffusion Model (REEDM), are typically used to estimate the impacts of emissions from launches. These models calculate peak concentrations and surface deposition near the launch pad and downwind. The models are based on inputted meteorological data such as wind speed, cloud height, wind direction, air temperature, atmospheric pressure, and relative humidity.

As the LV gradually accelerates off the launch pad, the emission levels are greater near the ground, forming the 'ground cloud.' For some medium and larger launch vehicles, this cloud may rise to 1 km or more before stabilizing. Its height remains relatively constant as it is transported and dispersed downwind.[98] The ground cloud can be generated by gaseous and aerosol phases of the exhaust products. The aerosols are generally water droplets containing dissolved HCl and particulate Al_2O_3. The larger droplets tend to deposit near the launch pad. The quantity of aerosol deposition is affected by the amount of deluge water used, the amount of water produced by combustion, and the water content and temperature of the ambient air that mixes with the ground cloud. The amount of aerosol is less with a drier ground cloud.[99]

Hydrogen Chloride. HCl is an HAP and is toxic, corrosive, and an irritant. EPA regulates 188 HAPs, including HCl, but launch vehicles are not included as one of the regulated source categories. However, because HCl is toxic, its impacts are considered for this PEIS. In the troposphere, HCl emissions from LVs are estimated to be approximately 7 to 29 tons per launch for vehicles that use SRMs (see Table 5-2).

To analyze the impacts of the ground cloud, the quantity of HCl is compared to the HCl threshold limit value (TLV) (the exposure limit value set by the Occupational Safety and Health Administration (OSHA) protecting workers over an 8-hour day and a 40-hour week). In this case, the TLV is 5 ppm or the one-time short-term public emergency guidance level (SPEGL) developed by the National Research Council of 1 ppm as a ceiling concentration.[100] The TLV expresses the upper limit of a toxicant concentration that a healthy human being can be exposed to on a daily basis without experiencing adverse health effects. Modeling using REEDM conducted for other analyses has shown HCl concentrations of 0.9 ppm for the Space Shuttle, 0.005-0.5 ppm for the Titan III, 0.22 ppm (one-hour average) for the Titan IV-Type 1 with SRM (the maximum one-hour average HCl value for the nearest Vandenberg off-base location is 1.0 ppm), and less than 2 ppm (30 minute average) for Athena, formerly called LMLV-2.[101,102,103,104] Studies of the Titan III and the Space Shuttle have shown maximum HCl concentrations at the TLV of 5 ppm for 10 to 60 minutes after the launch at 1 to 2 kilometers above ground level. REEDM also predicted a maximum HCl ground-level concentration of 0.8 ppm at a downwind distance of 8 miles from the Atlas IIAS. Maximum ground level concentrations of 1.2 ppm were predicted for the conflagration of the Atlas IIAS vehicle, and 1.8 ppm for the burning of the solid rocket motor storage facility.[105]

As shown in Appendix A, a conservative (resource protective) estimate of programmatic launch HCl emissions to the troposphere over an eleven year period is approximately 2,292 tons. Even if all of these HCl emissions occurred in one year, the impacts on acid rain would be minimal. Acid rain is formed when the HCl reacts with moisture in the air (e.g., rain) and deposits on the ground. These HCl emissions can be compared to the annual U.S. SO_2 emissions, the major pollutant contributing to acid rain in the U.S. The total allowable levels of electric utility SO_2 emissions from fossil fuel combustion; industrial processes; solvent use; waste incineration; and fossil fuel production, distribution, and storage in the U.S. are estimated to be 21 million tons for 1994. In comparison, estimated programmatic launch HCl emissions would represent only a very small fraction (< 0.001%) of the U.S. acid-rain producing emissions.

On a local level, the effects of acid rain may be somewhat more significant. HCl from LVs may contribute to acid rain that can change the pH levels in surface water, killing small fish and damaging or potentially killing trees and vegetation. Intermediate to high payload capacity vehicles have resulted in acid rain with a pH of one at about five km from the launch pad and a pH of two at about 10 km away. Based on high payload capacity vehicle launches using solid rocket motors, modeling has estimated the pH levels of rain to be less than one for up to 20 km from the launch pad and less than or equal to two up to 200 km away.[106] A more recent study using REEDM for several different LV systems showed that surface waters at both Cape Canaveral Air Station and Vandenberg Air Force Base have ample alkalinity to neutralize the maximum acid deposition. Furthermore, this study showed that the impacts of LV emissions drop off significantly (>50 percent) at approximately 1 km from the launch site. Usually, the impacts of acid rain occur within less than one-half mile from the launch pad. For large capacity vehicles (using solid propellants), acid rain has been shown to affect areas within one-half mile of the launch pad.[107]

The cumulative impact of HCl caused by launches has not been studied significantly to report in this PEIS. Scientists do think this may be an issue that warrants study and are beginning research projects to determine what, if any, cumulative effect HCl generated from launches would have on the atmosphere. The results of any credible studies would be subject to further analysis during site-specific environmental analysis and documentation.

<u>Aluminum Oxide.</u> Al_2O_3 is not toxic, but is particulate matter that could potentially cause irritation and damage to human respiratory tracts if it bypasses the natural human filtering systems. EPA has recently proposed revised standards for particulate matter equal to or less than 10 microns and additional more stringent standards for particulate matter equal or less than 2.5 microns in size. Some portion of particulate matter from launch vehicle emissions could be equal to or less than 2.5 microns in size. For example, greater than 50 percent of particulate matter emitted by the Delta II graphite epoxy motors (GEMs) are less than or equal to 10 microns. Only particulate matter equal to or less than 10 microns in size is regulated by EPA. Most of the particles of Al_2O_3 are assumed to be greater than 10 microns in size. In the troposphere, emissions of Al_2O_3 from LVs are estimated to be 12 to 52 tons per launch for LVs with solid rocket motors.

The specific effects of particulate matter on air quality are dependent on meteorological data (wind speed and direction, mixing heights of air, temperature) and site-specific receptors. To determine the impacts of Al_2O_3, modeled concentrations may be compared to the National Ambient Air Quality Standards for PM_{10} (150 $\mu g/m^3$ for 24-hour average and 50 $\mu g/m^3$ for annual average). One modeling analysis used REEDM to estimate concentrations of particulate matter (115-870 microns in size) for a Titan IV-Type 2 launch vehicle. The analysis estimated that particulate matter concentrations for 24-hours were 25 $\mu g/m^3$ above background PM_{10} concentrations.[108]

The cumulative impact of AL_2O_3 from LV launches, much like the cumulative impact of HCl, has not been studied. Should any credible studies be completed, their results would be subject to further analysis during site-specific environmental analysis and documentation.

5.1.2. Stratosphere

In the stratosphere, LV emissions could potentially affect global warming (the greenhouse gas effect) and depletion of the stratospheric ozone layer.

Global Warming. The Earth absorbs energy from the sun and radiates this energy back into the atmosphere. The greenhouse gas effect, or global warming, results when the re-radiated energy is trapped by gases in the atmosphere and warms the Earth's surface and atmosphere. Greenhouse gases include water vapor, carbon dioxide, methane, ozone, chlorofluorocarbons (CFCs), hydrofluorocarbons, and perfluorinated carbons. Note that ozone exists in both the troposphere and stratosphere. Most ozone is found in the stratosphere where it provides a protective layer shielding the Earth from ultraviolet (UV) radiation and subsequent harmful effects. Some ozone is transported to the troposphere. In the troposphere, ozone is a chemical oxidant and a major component of smog.

Other photochemically important gases such as carbon monoxide (CO), nitrogen oxides (NO_x), and nonmethane hydrocarbons (NMHC) are not greenhouse gases, but contribute indirectly to the greenhouse gas effect. These indirect contributors influence the rate at which ozone and other gases are created and destroyed in the atmosphere.

The potential LV emissions that may affect global warming include water vapor and CO_2. For most greenhouse gases, a global warming potential has been developed to allow for comparison of the ability of each greenhouse gas to trap heat in the atmosphere. However, no global warming potential has been developed for water.

The total CO_2 emissions range from 15 to 257 tons per launch, depending on the LV's payload capacity and propellant type. The estimated total CO_2 emissions from launches into the troposphere for the period 2000-2010 is approximately 25,000 tons (see Appendix A). In comparison, the total CO_2 emissions from all sources in the U.S. was 5,687 million tons in 1994. Even if all of the launches occurred in one year, based on 1994 CO_2 emission levels, these launches would only be a very small fraction (less than 0.00005%) of the total CO_2 emissions. Consequently, the CO_2 emission effects from LVs on global warming would be insignificant. The total water vapor generated is approximately 9 to 94 tons per launch, or about 12,000 tons for the period 2000-2010 into the troposphere. In comparison, the total carbon-equivalent direct and indirect emissions effects (excluding the photochemically important emissions) in the U.S. were 1,835 million tons in 1994. Water vapor from LVs would also have an insignificant effect on global warming.

Ozone Depletion. Stratospheric ozone layer depletion is a major environmental concern. The stratospheric ozone layer protects the Earth from adverse levels of UV radiation. Excess UV exposure can lead to increased incidences of skin cancer, sunburn, and immune deficiencies. The protective ozone layer is mostly contained within the stratosphere, an area that extends from approximately 10 kilometers to 50 kilometers above the Earth's surface.

As stated in section 3.1.2, the highest concentrations of ozone are found in the middle of the stratospheric layer and ozone is continually created and destroyed by naturally occurring photochemical processes. Ozone is made up of three oxygen atoms and is generated by the action of sunlight to combine an O_2 with an atom of oxygen. Conversely it can be destroyed through a series of photochemical reactions that can catalyze the reactions $O + O_3 = 2O_2$ and $2O_3 = 3O_2$ of compounds that break up O_3 into various other compounds. The following presents the chemical and photochemical processes that are important in the formation of ozone from molecular oxygen in the stratosphere and the reactions associated with ozone destruction.

Ozone Destruction[109]

$O_3 \rightarrow O + O_2$

$O_3 + O \rightarrow 2O_2$

$Cl + O_3 \rightarrow ClO + O_2$

$ClO + O \rightarrow Cl + O_2$

$H + O_3 \rightarrow HO + O_2$

$HO + O \rightarrow H + O_2$

$OH + O_3 \rightarrow HO_2 + O_2$

$O + HO_2 \rightarrow OH + O_2$

$NO + O_3 \rightarrow NO_2 + O_2$

$NO_2 + O \rightarrow NO + O_2$

Ozone Production

$O_2 \rightarrow 2O$

$O + O_2 + M \rightarrow O_3 + M$

Chlorine is the chemical of primary concern with respect to ozone depletion. Human activity has significantly contributed to the chlorine load levels in the stratosphere. Chlorine accounts for approximately 13% of ozone destruction.[110] Launches are one of the anthroprogenic (man-made) sources of chlorine in the stratosphere.

Emissions from launch vehicle engines, including licensed launches, are of concern because during about 60 seconds of an LV ascent the LV injects substances that can lead to ozone depletion (HCl, Al_2O_3, NO_x, and Cl) directly into the stratosphere. For example, studies have shown the percent reduction of ozone per ton of HCl is 2.8×10^{-5}, 7.5×10^{-6} for Al_2O_3, and 1.6×10^{-6} for NO.[111,112,113]

Under the preferred alternative, the emission load of HCl in the stratosphere for all U.S. licensed launches from 2000-2010 is approximately 2,292 tons and additional free Cl load is 31 tons. This averages to approximately 211 tons of HCl and Cl load to the stratosphere from U.S. licensed launches per year. Before Cl can deplete ozone, the HCl must be photolyzed (i.e., light must interact with the HCl molecule and release Cl) and the resulting Cl can then deplete ozone. Some of the HCl in the troposphere can mix with water and be rained out of the atmosphere before it has a chance to release Cl, thus reducing some destruction of ozone by Cl.

Beside gases, SRMs release particulates and Al_2O_3. Attempts to determine the distribution and effect on ozone depletion of particulates and Al_2O_3 have been limited. Therefore the current models are based upon homogenous gas phase chemistry, which act as a site for the ozone depleting reaction. The significance of this stage is unclear. Heterogeneous chemistry (which accounts for particulates, plume temperature and afterburning of fuel-rich exhaust) is not included in this PEIS, because there are very limited data and modeling available to date. However, future analysis of launches using heterogeneous chemistry could alter the understanding of potential impacts of launches on stratospheric ozone-depletion.[114] In terms of local ozone depletion in the general exhaust of the LV limited field data and several computer models have estimated local ozone depletion from 7 to 40 percent for several minutes to hours after the launch. Winds rapidly disperse the exhaust and return the ozone to approximately normal levels.

The recent field study on Rocket Impact on Stratospheric Ozone (RISO) has confirmed that ozone depletion related to launch emissions is a temporary and limited phenomenon. Initial results from this study have indicated that LO_x/kerosene engines may be more potent in ozone depletion than previously expected. Thus additional data collection is ongoing to further evaluate LO_x/kerosene exhaust impacts. Ground-based light detection and ranging equipment results from this study have indicated that (1) the relative rates of plume expansion and diffusion are quite different than previously assumed; (2) stratospheric plumes stratify into stable layers of only several hundred meters thick; and (3) large SRM aerosol emissions consist of alumina and an additional aerosol that disappear within 90 minutes of launch and do not appear in plumes above approximately 35 km. In general, preliminary findings from this study indicate that the potential for ozone depletion associated with LV exhaust to cause an increase in solar UV intensity near launch sites is extremely limited.[115]

There has been extensive research on the potentially harmful effects of large solid rocket motor exhaust on global ozone depletion by the Air Force and the National Aeronautics and Space Administration (NASA). These studies are generally based on a high launch rate, which allows for evaluation of large HCl and Cl loads to the stratosphere. One such study by the World Meteorological Organization examined the effects of ten launches of each of the following vehicles per year: Space Shuttle, Titan IV, and Ariane 5, which release 68, 32, and 57 tons of Cl per launch, respectively, directly into the stratosphere.[116] A total of 1,570 tons of Cl deposited in the stratosphere each year from these launches corresponds to only 0.064% of the 1994 total stratospheric burden of chlorine from industrial sources.[117] Analyses in the RISO study have confirmed that ozone loss occurs in the plume wakes of large SRMs (e.g., Titan IV and Space Shuttle), but the amount and duration of the loss appears to be temporary and limited. Interestingly, the effect is greater with the Titan IV as compared to the Shuttle, but the differences in the causative plume chemistries are not well understood.[118]

In comparison, SRMs on LVs used for licensed launches are smaller than those on the Space Shuttle and the upgraded SRMs on the Titan IV. The specific HCl input to the stratosphere from launch exhaust can be estimated if the HCl amount and its time-dependent releases along the ascent are known. Using the number of launches estimated in Section 2.0, emission loads of HCl in the stratosphere for all U.S. licensed launches from –2000-2010 are approximately 2,292 tons, and the additional free Cl load is 31 tons. This averages to approximately 211 tons of HCl and Cl load to the stratosphere from U.S. licensed launches per year. (See Appendix A, Emission/Afterburning Products and Loads for a detailed methodology determining numbers and emissions loads.) The RISO study results indicate that ozone depletion related to alumina emissions from SRMs is proportional to the fraction of alumina in the smallest size mode. Previous estimates have suggested that about 10 percent of SRM alumina is in the smallest size mode, while RISO measurements indicate that only about 0.1 percent of SRM alumina is in the smallest mode. This suggests that the role of SRM-emitted alumina may be less important in global atmospheric reactions than was previously estimated.[119]

In the environmental assessment of the Atlas IIAS,[120] a comparison was made between the effect of an Atlas IIAS and a Titan IV on ozone depletion. The ozone depletion from three Titan IV launches per year would be approximately 0.01% - a conservative estimate because it assumed all of the emissions would migrate to the stratosphere. An Atlas IIAS launch would emit approximately 7.9 tons of HCl, compared to 145.5 tons emitted by a Titan IV launch. Therefore, by simple ratio, the estimate of peak ozone depletion due to six Atlas IIAS launches per year would be 0.001% of total ozone depletion.

Another study entitled "Atmospheric Environmental Implications of Propulsion Systems" concluded that even vastly increased launch activities (50 Space Shuttle or Energia launches per year) would not significantly impact stratospheric ozone depletion.[121] A comparison in this study was made between the chlorine loads in the stratosphere from launches and the chlorine loads from other natural and man-made sources. The primary sources of ozone depleting chemicals are CFCs and other man-made ozone-depleting chemicals, and natural sources from the oceans, burning vegetation, and volcanic eruptions. It is also noted in this article that LVs release mostly HCl into the stratosphere. Thus, although the preferred alternative would increase the Cl load to the stratosphere, the global effects would be far below and indistinguishable from the effects caused by other natural and man-made causes. Even with the production ban on CFCs, HCFCs, and methyl bromide, LV exhaust from licensed launches (similar to any given man-made source of HCl considered in isolation) would remain an insubstantial part of the overall chlorine load to the stratosphere over the next 50 years due to the long-life of CFCs. Nonetheless, the serious nature of the problem of ozone depletion implies that all sources must be considered. Hybrid propulsion systems have the potential to greatly reduce the HCl emitted from LV exhaust into the stratosphere. The hybrid propulsion systems, currently undergoing testing, burn solid fuel (aluminum) and a cryogenic oxidizer (LO_x). Thus, these propellants do not release HCl when burned.

In summary, the LV emissions that may affect global warming include water vapor and CO_2. However, there is currently no way to study the effects of water vapor from LV emissions on the greenhouse effect. The total amount of CO_2 that is released from launches is thought to be so much less than the contributions of CO_2 by other industries as to make launches an insignificant source of CO_2. Protecting the stratospheric ozone layer is a major global concern. Emissions from licensed launches do contribute to the creation of "holes" in the stratospheric ozone layer as the LV passes through although these "holes" tend to "fill back in" rapidly following a launch.[122] The amount of depletion depends on the type of propellants used.

5.1.3 Accidents in the Troposphere and Stratosphere

The impacts from accidents on the launch pad or as a result of a flight anomaly requiring the use of a flight safety system may impact the air quality in the atmosphere at the time of the accident. However, because of the infrequency of these events, the overall impact in comparison to other emission sources is not substantial. The impacts of accidents are typically described by propellant type. However, some LVs, especially medium and high capacity vehicles may use a combination of propellant systems.

Accidents on the launch pad would result in significant air emissions. The impacts would differ from normal flights because all or a larger portion of the propellant would burn at the launch pad or within the first 10 seconds after ignition.

<u>SRMs.</u> The emissions of most concern for LVs using solid propellant systems are HCl, CO, CO_2, Al_2O_3, and NO_x. The rate at which the solid propellant would burn depends on the size of the solid fuel fragments and the air pressure.[123] Open burning of all the propellant may release approximately 3,200 kg (3.5 tons) of HCl emissions; 3,520 kg (3.9 tons) of CO_2 emissions; 2,720 kg (3 tons) of CO emissions; 6,434 kg (7 tons) of Al_2O_3 emissions; and 550 kg (0.6 tons) of NO_x emissions, based on the CASTOR 120™ boosters and approximately 49,033 kg (108,100 lb) of propellant. Solid propellant is broken into relatively small pieces and only a small percent of it burns completely. Therefore the

amounts released from a failed vehicle launch may be less than these estimates; however, emissions would be higher from vehicles with larger solid rocket motors.

The HCl may combine with moisture in the air and form hydrochloric acid. This vapor may exist in hazardous quantities in the immediate vicinity of the launch pad and downwind. High wind conditions (greater than 4 miles per hour) and strong sunshine could dissipate the HCl concentrations.[124] The HCl may also be washed out by moisture in the air causing acid rain most likely within close proximity to the launch pad.[125] The CO and NO_x emissions could impact the air quality in the area for that day especially if the area is nonattainment and does not meet the National Ambient Air Quality Standards for CO, NO_x or ozone (since NO_x is a precursor). The NO_x emissions could also contribute to local acid rain. The CO_2 emissions could affect global warming, but compared to other sources of CO_2 emissions, accidents would result in negligible impacts. The Al_2O_3 emissions would primarily occur in particle form from the burned solid propellant.

<u>LO_x-RP1</u>. For LVs using LO_x-RP1 propellants, hybrid propellants, or hydrogen peroxide, the CO_2 emissions would be the most significant. As noted below, the CO_2 emissions could affect global warming, but even with the open burning of all the propellant, these emissions from LV accidents would be negligible compared to the rest of the CO_2 emissions sources in the U.S. and worldwide.

<u>H_2O_2</u>. Concentrated hydrogen peroxide has been used in several launch systems and is proposed to be used in several new launch vehicles as both a monopropellant as well as in combination with kerosene or alcohol based fuels. Vehicles using hydrogen peroxide would be expected to have emissions similar to LOx-RP1 propelled systems.

<u>Hypergols</u>. If a launch vehicle had a rapid, sudden explosion of hypergolic propellant (mainly nitrogen tetroxide (N_2O_4)-aerozine-50 (a mixture of 50 percent, by weight, hydrazine and 50 percent unsymmetrical dimethylhydrazine) (A-50)), the release of N_2O_4 would create NO_2 emissions. For the Titan IV, the REEDM model was used to characterize this type of event. For this modeling, 80 percent of the N_2O_4 and 20 percent of the A-50 was assumed to remain unreacted. These assumptions were based on an observation of a destruction of the Titan 34D at 800 ft above the launch pad in 1986. Assuming that the hypergolic propellant system in a Titan IV LV is about 155,000 kg, the amount of N_2O_4 (approximately 102,000 kg) would be almost twice the amount of A-50 (approximately 51,000 kg). The N_2O_4 disassociates almost completely in the ambient air and forms NO_2. This modeling analysis of the Titan IV predicted that the maximum one hour NO_2 concentrations would be 1.09 ppm at a distance greater than 10 miles (16 km). This concentration exceeds the SPEGLs recommended by the National Research Council 1-hour concentration of 1.0 ppm.[126] The toxic NO_2 emissions from accidents may impact the air quality in the region of the launch pad perhaps endangering any nearby residents. NO_x may also contribute to the development of acid rain. With the NAAQS, EPA regulates NO_x emissions alone and as a tropospheric ozone precursor, although not specifically from LVs. EPA does not provide a maximum NO_x concentration level for a short-term averaging period; however, a short-term (1-hour) standard is provided for ozone (0.12 ppm). The relationship between NO_x and O_3 is complex. Sometimes, NO_x emissions contribute to the formation of ozone; other times, NO_x emissions prevent ozone formation.

Cryogenics. LVs using cryogenic propellants, LO_x and LH_2, would mainly emit water vapor.

Accidents where a flight safety system is activated may result in the burning of the remaining propellant in the atmospheric layer where the termination occurs. If the accident occurs in the troposphere, all of the propellant may burn. The emissions would be similar to those described for an accident on the launch pad; however, the impacts may not be as localized. For accidents with flight safety system activation in the stratosphere, the remaining propellant may burn. The emissions from such an accident, would be expected to be insignificant with respect to global warming and most likely less than the emissions expected from a normal, full duration launch.

5.1.4 Accidents in the Mesosphere

In this analysis, no impacts to the mesosphere are predicted during nominal launches. If an accident occurs in the mesosphere, the emissions would be greater than a launch pad accident, but no additional impacts would be predicted on the mesosphere.

5.1.5 Accidents in the Ionosphere

Some exhaust products from LVs generated during launch from Earth to space have been found to have a temporary effect on electron concentrations in the F layer of the ionosphere. Specifically, these exhaust products are CO_2, water, and atomic hydrogen. These compounds can react with ambient electrons and ions in the F layer of the ionosphere to effectively form a "hole" in this region by reducing the concentration of electrons and ions within the path of the vehicle.

This effect in the F layer is believed to be caused by a rapid charge-exchange reaction between the LV exhaust products and the ambient atomic oxygen ions in the F layer. Ambient atomic oxygen ions (O+) are the dominant ion in the F layer. At lower altitudes of the ionosphere (i.e., below 140 km), this reaction is not effective because the dominant positive ions are NO^+ and O_2^+, not O^+. For example, the reaction between water and O+ is as follows:

$H_2O + O^+ \rightarrow H_2O^+ + O$ followed by the rapid recombination
$H_2O^+ + e^- \rightarrow OH^- + H^-$

Similar reactions also occur with carbon dioxide and hydrogen. These reactions result in a net decrease in electron concentration in the F layer, potentially affecting radio communication, such as short-wave broadcasts, which interact with the ionosphere.[127]

An experimental test firing of the propulsion unit used by the Space Shuttle for maneuvering within the ionosphere was conducted in 1985. This test firing provides some data on the rapidity with which a "hole" in the F layer may disappear. The propellants used in this test firing were monomethylhydrazine (MMH) and nitrogen tetroxide (N_2O_4), similar to the propellants used for routine launches of other LVs. However, the quantities of propellants consumed for this test are smaller than the quantities of propellants consumed during launches of medium to large-scale capacity LVs.

The test involved consuming 290 kg (640 pounds) total mass of MMH and N_2O_4. Exhaust products from this experimental test firing consisted of approximately 117.7 kg (40.6 percent) nitrogen, 92.5 kg (31.9 percent) carbon dioxide, 75.7 kg (26.1 percent) water, and 4.1 kg (1.4 percent) hydrogen. The percentages represent percent by mass, and complete combustion was assumed. Thus, about 172 kg of potential electron-depleting substances (CO_2, H_2O, and H) were emitted. The associated "ion/electron hole" disappeared into the lower F layer within five minutes.

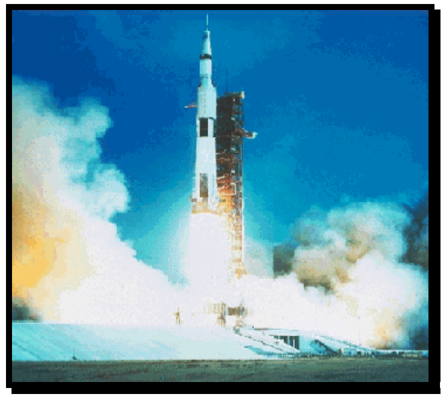
This quantity of by-products represents only 0.2 percent of by-products produced in the upper atmosphere during a typical launch from Earth to space.[128] Using the same methodology used in Appendix A of this PEIS to estimate emission loadings to the stratosphere and troposphere, rough estimates of electron-depleting loadings to the ionosphere were also calculated. These loadings were estimated for the four vehicle capacity types (i.e., small, medium, intermediate, and high) and three categories of propellant type (solid, liquid and hybrid, and hypergolic). A small vehicle burning only solid propellant would emit approximately 100 kg of electron-depleting substances (CO_2, H_2O, and negligible H), similar to the test results above. However, a medium vehicle burning both solid and hypergolic propellants in the ionosphere would emit approximately 2,400 kg of electron-depleting substances (CO_2, H_2O, and H), 14 times greater than the test results above. Table 5-3 provides estimates of propellant consumption in the ionosphere by vehicle capacity category and propellant type.

TABLE 5- 3
ESTIMATED PROPELLANT CONSUMPTION IN THE IONOSPHERE BY VEHICLE CAPACITY CATEGORY AND PROPELLANT TYPE

	Solid	Cryogens	Hypergolic	Hybrid
Small	1000 kg			
Medium	5000 kg		4,500 kg	
Intermediate	20,000 kg	20,000 kg	20,000 kg	20,000 kg
High		32,000 kg	32,000 kg	32,000 kg

Data are unavailable to estimate the differences in the size of the "ion/electron hole" that might be created with larger vehicles and the amount of time it would take for these holes to dissipate. As stated earlier, an important variable concerning whether or not there would be ionospheric effects is location of the final parking orbit. For example, the 12 Saturn V LVs launched during the Apollo program did not cause an ionospheric hole measurable from the Earth's surface because all of their final parking orbits (and therefore their second stage burns) were below 190 km (where the ionospheric chemistry is different from the F-layer). (See Figure 5-1)

Figure 5-1
Saturn V Launch Vehicle (1969)



However, the Saturn V launch of Skylab did create a sizable ionospheric hole, because orbital insertion of this launch occurred at 442 km.[129] In the worst case, these holes appear to dissipate in a matter of minutes. Therefore, it does not appear that the effects of this phenomenon could accumulate to any degree, unless there were launches through the same region of the atmosphere every few minutes.

5.2 Potential Noise Impacts of the Preferred Alternative

The noise impacts are assessed by receptor type. In the affected environment (Section 3.2), the activities under the preferred alternative which could potentially lead to impacts are described (e.g., launches, sonic booms). In this section, three receptor categories are identified: humans (subsection 5.2.1), wildlife (subsection 5.2.2), and structures (subsection 5.2.3). For each type of receptor, the potential impacts of launch activities are detailed in the appropriate subsection.

5.2.1 Noise Impacts on Human Beings

Human annoyance is best predicted by L_{dn} levels, as detailed in Section 3.2. There are two different methods to accomplish this: predict the overall noise level and/or predict the increase in noise level. There is fairly good agreement that L_{dn} levels above 65 dBA affect communities. Furthermore, studies have been done which predict annoyance and community reaction as a function of L_{dn}. Data presented by EPA indicate that at 65 L_{dn}, 30 percent of the population is "highly annoyed," resulting in 5 percent filing complaints and some threats of legal action. Other survey results suggest that the 65 L_{dn} may only result in about 15% of the population being "highly annoyed."[130] Increments of 3 dBA are usually associated with the lowest increase perceptible to the human ear.

There are two reactions people may have to single event noise from licensed launches. The first is an uncomfortable feeling due solely to the noise level. The second is a startle effect, due to the impulse noise of sonic booms and their associated noise levels. Preliminary results of recent research suggest that people are more sensitive to sonic boom noise than other types of noises at similar levels, including aircraft noise around airports. Therefore, the effects of sonic booms are discussed separately below. Based on predicted dBA levels, people may perceive launch related noise to be "very loud" out to a distance of 3 miles. Assuming no barriers lessen the noise, the level would be considered "loud" anywhere from 10 to 35 miles from the launch pad.

There are three concerns regarding sonic boom effects on humans: (1) health, (2) startle, and (3) annoyance. To put these concerns into perspective, Table 5-4 presents overpressures and common noise sources. In the expected overpressure range for the proposed activities, two to three pounds per square foot (psf), a cap gun or firecracker near the ear would be an equivalent noise source. Each of the concerns is discussed below.

TABLE 5-4
TYPICAL SONIC BOOM OVERPRESSURE RANGES AND EQUIVALENTS

Overpressure (psf)	Common Equivalent
0.5 - 2	Pile driver at construction site
2 - 4	Cap gun or firecracker near ear
4 - 10	Handgun as heard at shooter's ear
10 - 14	Fireworks display from viewing stand

In 1986, an epidemiological study of health effects related to sonic booms was published. This was a statewide study of Nevada; chosen because sonic booms were carried out longer there than any place else in the U.S. It concluded that there was: "no convincing evidence to prove or disprove any relationship between exposure to sonic boom and adverse health phenomena."[131] A 1990 course on sonic boom effects concluded that there was no evidence of health effects and that hearing damage was "definitely not a problem."[132] The Committee on Hearing, Bioacoustics, and Biomechanics of the National Academy of Sciences/National Research Council has recommended an exposure limit of one impulse/day at 7.25 psf.[133] Based on the above, no health effects are anticipated.

Sonic booms cause human reactions similar to those produced by storm thunder. This can cause a startle effect. Startle effects involve involuntary movement (muscular reflexes). One concern with this type of reaction is the potential increase for accidents. In the anticipated range of two to three psf these may include eye blinking in about 50% of the subjects and arm/hand movements in about 25% of the subjects, but no gross bodily movements.[134] Another study found that this range would result in arm/hand movement in about 10% of the subjects but had no affect on automobile driver performance.[135] Although, as of 1990, there has been no known record of injury or trauma due to sonic booms, the potential for impacts remains.

Annoyance created by sonic booms is a function of boom intensity, number of booms per time period, attitude of the population, and the activity in which people were engaged in at the time of the boom. There is no precise relationship between the parameters. The results of various studies are presented below.

One study found that 10% of the subjects exposed to 10-15 booms per day were annoyed at an overpressure of one psf and that this reached nearly 100% at three psf.[136] However, people may be more sensitive when exposed to numerous booms per day, while prior experience with sonic booms (such as people who live on an Air Force base) seems to lower sensitivity. Other studies indicate that there is a wide range in estimating percent annoyed ranging from 10% to 70% at one psf and 55% to approximately 100% at three psf.[137]

Research was conducted during the 1960's and 1970's to determine the likely effect of commercial supersonic jet aircraft on the environment, focusing on the effects on humans. The physiological reactions most commonly found to be associated with sonic booms included: involuntary muscle spasms, orientation reactions, increase in heart rate, and involuntary eye blink.

The introduction of commercial and military supersonic aircraft has further raised the question of whether sonic booms should be considered as severe environmental pollution, with adverse effects on humans, animals, and structures.[z] Reviewers of Air Force proposals for new low-altitude training routes and military operating areas frequently express concern regarding the effect of jet noise on wildlife and farm animals.[aa] A sudden or unfamiliar sound is believed to act as an alarm, activating the sympathetic nervous system. The short-term physiological stress reactions, referred to as "fight-or-flight," are similar for many vertebrate species.[bb] The general pattern of response to stress includes activation of the neural and endocrine systems, causing changes such as increased blood pressure, available glucose, and blood levels of corticosteroids. For these reasons, sonic booms and the startle and annoyance effects they induce in humans and animals should be considered as potential health impacts to these species.

Another measure of noise is provided by EPA's blast noise recommendation. The recommendation is to limit the level to 125 dB (unweighted) at sensitive receptors. Sonic booms may exceed this recommendation for an estimated two to 15 miles from the source.

As noted, the types of interference and activities people are involved in affect annoyance. Table 5-5 presents the results of a St. Louis study of annoyance involving multiple sonic booms.[138]

TABLE 5-5
EXAMPLES OF ANNOYANCE LEVELS FOR VARIOUS TYPES OF ACTIVITIES

Type of Interference/Activity	Percent Annoyed
House Shaking	38
Startled	32
Sleep	22
Rest	15
Conversation	10
Radio/television	7

In a similar study in Oklahoma City,[139] results were fairly comparable, except that a significantly higher portion of the subjects were annoyed when their houses were shaken (55% as opposed to 38%). However, EPA reported reversed order, for the last four activities, due to aircraft related annoyance.[140]

The preliminary findings in the most recently-published literature seem to indicate that: (1) people are more sensitive to sonic booms than previously thought and that existing community

[z] Cottereau, P. 1978. Effect of sonic boom from aircraft on wildlife and animal husbandry. Pages 63-79 in J.L. Fletchers and R.G. Busnel, eds. Effects of Noise on Wildlife. Academic Press, New York. In Manci, K.M., D.N. Gladwin, R. Villella, and M.G. Cavendish. 1998. Effects of aircraft noise and sonic booms on domestic animals and wildlife: a literature synthesis. U.S. Fish and Wildlife Service. National Ecology Research Center, Ft. Collins, CO. NERC – 88/29. 88 pp.

[aa] Shotton, L.R. 1982. Response of wildlife and farm animals to low-level military jet overflight. Reporter II (6): 161-164. In Manci, K.M., D.N. Gladwin, R. Villella, and M.G. Cavendish. 1998. Effects of aircraft noise and sonic booms on domestic animals and wildlife: a literature synthesis. U.S. Fish and Wildlife Service. National Ecology Research Center, Ft. Collins, CO. NERC – 88/29. 88 pp.

[bb] Moller, A. 1978. Review of animal experiments. J. Sound Vib. 59: 73-77. In Manci, K.M., D.N. Gladwin, R. Villella, and M.G. Cavendish. 1998. Effects of aircraft noise and sonic booms on domestic animals and wildlife: a literature synthesis. U.S. Fish and Wildlife Service. National Ecology Research Center, Ft. Collins, CO. NERC – 88/29. 88 pp.

annoyance models do not capture this effect, and (2) people perceive sonic booms as more intrusive than aircraft noise at comparable levels. At an L_{dn} of 25 to 35 dBA the preliminary results indicate that 27% of the subjects were a little annoyed, 22% were moderately annoyed, and 30% were very much annoyed. These people related sonic boom noise to “hearing big noisy trucks if you lived near an intersection or having a dog next door that regularly barks in the middle of the night.”[141]

5.2.2 Noise Impacts on Wildlife

Effects on wildlife in natural situations from sonic booms produced by LVs are difficult to study or predict. In general, mammals and raptors do not panic when exposed to sudden intense noises, whereas waterfowl are more likely to startle and possibly injure themselves or their young when suddenly frightened.[142, 143]

Birds are most sensitive to noise in the 1,000 to 5,000 Hz range. This is far higher than frequencies associated with launches, especially sonic booms which have much of their energy below 100 Hz. Birds, however, may be startled by impulsive noises created by launches and the result may be flushing.[144] This may begin to occur at noise levels of 80 to 85 dBA. The effect would most probably be of short duration. That is, birds would return to nests, usually within minutes. Birds commonly nest and forage in and around airports and even under supersonic operating areas. No mortality or reduction in habitat usage has been observed within 800 feet of the Titan launch complex or within one mile of the Space Shuttle.[145]

Mammals seem to be less disturbed by noise than birds, but startle effects can occur. “Intense” sonic booms resulted in an alert and startle effect on bighorn sheep, while the endangered Sonoran Pronghorn was reported jumping and running.[146] However, there has been no “substantial effect on wildlife in or near the launch complex” for Space Shuttle or Titan IV launches.[147] Research by the U.S. Air Force on sonic boom effects on wildlife has found that:

> After fewer than five exposures, most animals become habituated to the noise and show little response. In research conducted on pronghorn antelope, Rocky Mountain elk, and bighorn sheep, exposure to sonic booms caused a light rise in heart rate after the initial disturbance. The startle responses decreased for subsequent booms and were soon less than those evoked by humans walking into animal pens, or bees and biting flies bothering the animals.[148]

Young sea lions and seals (pups), which are called pinnipeds, were tested to determine their physiological response to noise. The testing determined their temporary threshold shift. This is the temporary change in their ability to hear. It may be important as it could affect their ability to find food, social behavior, and survival. For example, the temporary threshold shift for Northern Elephant Seals lasted approximately 20 minutes at a pressure of 6.9 psf.[149] In harbor seals the temporary threshold shift lasted 90 minutes at a pressure of 7.2 psf.[150] The implications of these temporary threshold shifts have not yet been quantified.

Observations of pinniped and bird responses to Titan IV launches have been documented. These have taken place at Vandenberg AFB and in the Channel Islands, 30 to 40 miles from the launch pad at Vandenberg.

1. At Vandenberg AFB[151]

   - At a sound exposure level (SEL) of 99 dBA all 28 harbor seals moved toward the water, with 23 entering the surf.

   - At an SEL of 102 dBA all 41 seals rushed into the water. They began returning within 20 minutes and 75 percent returned within 90 minutes.

2. In Channel Islands

   - At a sonic boom of 1.2 psf there was no behavioral changes in elephant seals. About 25 percent of California sea lions responded with a heads-up alert. None moved toward the water and they returned to resting within 30 seconds. Furthermore, there was no response to light from launch, which lasted about two minutes.[152]

   - In response to a Titan explosion (at maximum noise levels [not recorded]) 45 percent of the sea lions and 2 percent of the Northern fur seals rushed into the water. Approximately 15 percent of the sea lion pups were separated from their mothers for one to two hours.[153]

   - At a sonic boom of 9 psf five of six harbor seals rushed into water; 90 percent of the northern elephant seals became alerted, but none moved; and Brandt's Cormorants moved toward the water, but did not enter the surf.[154]

   - At a sonic boom of somewhat less than 9 psf (no reading available) all California sea lions, not surrounded by elephant seals, rushed into the water. About 80 percent of the elephant seals became alerted and 25 of the 683 seals entered the surf.[155]

   - At a sonic boom of somewhat less than above, twenty of twenty harbor seals fled into the water. Approximately 30 percent of the northern elephant seals became alerted.[156]

   - Two hours after a sonic boom of 1.1 psf, three harbor seals were tested for temporary threshold shifts and permanent threshold shifts. "No detectable changes in seal's hearing occurred as a result of the launch" and the animals "appeared healthy and in excellent condition."[157]

Several observations regarding fish response to sonic booms have been made. They range from no effect on fish eggs to striped bass jumping out of tanks, resulting in death and dying from seizures in the water.[158]

Sonic booms from launches also impact underwater environments. These types of booms do represent a threat of physical and physiological impairment to marine animals in the vicinity of the water surface, particularly if these animals are in the relatively restricted impact zone of the boom. Sonic booms from LVs may reach underwater depths of 0.25 to one kilometer in depth, and under repeated occurrence, might affect the migrating route and habitat choice of certain marine animals.

Overall, it seems that most wildlife, excluding marine animals, respond more adversely to visual impacts than to audio impacts. For example, wildlife has been known to return to their habitat once construction has ceased, even though operations have been quite noisy, such as near airport facilities.

5.2.3 Noise Impacts on Structures

Table 5-6 provides estimates of damage as a function of overpressure. Because LVs would possibly produce an overpressure in the two to three psf range, damage could be caused at exposed buildings to glass, plaster, roofs, and ceilings.[159] In well-built and maintained buildings, glass would receive the primary damage. Approximately one in 10,000 panes may be broken at an overpressure of four psf.[160] The amount of damage experienced would vary depending on the pre-existing condition of the structure subjected to the sonic boom.

The expected impact from sonic booms on structures resulting from licensed launches would vary for different flight paths from each launch facility. Sonic booms are propagated towards the ground only when the vehicle pitches over during its flight. Therefore, sonic booms would only impact those structures that lie on the ground below the flight path of the vehicle after it has pitched over. Flight paths may be altered to avoid overflight of sensitive structures. Mission specific and launch specific criteria determine the impact of sonic booms on structures and not the distance the structures are located from the launch site.

TABLE 5-6
POSSIBLE DAMAGE TO STRUCTURES FROM SONIC BOOMS[161]

Sonic Boom Overpressure Nominal (psf)	Type of Damage	Item Affected
0.5-2	Cracks in plaster	Fine; extension of existing; more in ceilings; over door frames; between some plaster boards.
	Cracks in glass	Rarely shattered; either partial or extension of existing.
	Damage to roof	Slippage of existing loose tiles/slates; sometimes new cracking of old slates at nail hole.
	Damage to outside Walls	Existing cracks in stucco extended.
	Bric-a-brac	Those carefully balanced or on edges can fall; fine glass, e.g., large goblets can fall and break.
	Other	Dust fall in chimneys.
2-4	Glass, plaster, roofs, ceilings	Failures show which would have been difficult to forecast in terms of their existing local condition. Nominally in good condition.
4-10	Glass	Regular failures within a population of well-installed glass; industrial as well as domestic greenhouses.
	Plaster	Partial ceiling collapse of good plaster; complete collapse of very new, incompletely cured or very old plaster.
	Roofs	High probability rate of failure in nominally good state, slurry-wash; some chance of failures in tiles on modern roofs, light roofs (bungalow) or large area can move bodily.
	Walls (exterior)	Old, free standing, in fairly good condition can collapse.
	Walls (interior)	Inside ("Party") walls known to move at 10 psf.
Greater than 10	Glass	Some good glass would fail regularly to sonic booms from the same direction. Glass with existing faults could shatter and fly. Large window frames move.
	Plaster	Most plaster affected.
	Ceilings	Plaster boards displaced by nail popping.
	Roofs	Most slate/slurry roofs affected, some badly; large roofs having good tile can be affected; some roofs bodily displaced causing gale-end and will-plate cracks; domestic chimneys dislodged if not in good condition.
	Walls	Internal party walls can move even if carrying fittings such as hand basins or taps; secondary damage due to water leakage.
	Bric-a-brac	Some nominally secure items can fall, e.g., large pictures; especially if fixed to party walls.

5.3 Other Environmental Impacts of the Preferred Alternaitve

For each of the six environment types identified in Section 3.3, other potential environmental impacts of the preferred alternative are described in the following sections. Atmospheric and noise impacts have been previously addressed. Note that impacts from new construction are not within the scope of this proposed action.

5.3.1 Regional Climate/Atmosphere

The characteristics of the local atmosphere that affect the air quality impacts of launches include wind speed and direction, temperature, humidity and rainfall, atmospheric stability and mixing heights and the topography of the area. The wind speed may affect the area over which the ground cloud may be dispersed. For higher wind speeds, the ground cloud may dissipate faster. For lower wind speeds, the ground cloud may disperse more slowly and therefore pose a hazard further downwind. In coastal environments, the prevailing winds may blow the ground cloud in the direction of the ocean.

The amount of rainfall and humidity may increase the likelihood and quantity of acid rain from HCl rained out of solid propellant system launch exhaust. This reduces the HCl load in all layers of the Earth's atmosphere. The mixing height and atmospheric stability would also affect the impacts of launches. The more stable the atmosphere, the longer the ground cloud may remain over a particular area without much dispersion. Areas with great solar radiation tend to have less stable, more turbulent air atmospheres. Areas that are susceptible to inversion would tend to reduce the dispersion of the ground cloud. Certain meteorological conditions can exist where the higher layer of air is warmer than the air below, creating an inversion layer. This warmer region is the mixing region which, because of its height in the atmosphere, tends to trap air pollutants. Topography affects the ground cloud in that flatter terrain generally decreases dispersion. Temperature is usually only a factor in influencing the evaporation rate of liquid pools.

In analyzing the six types of local climates examined in this PEIS, the primary factors that would influence dispersion include wind speed, atmospheric stability and wind direction, although other special factors may come into play. For the Mid-Atlantic Coastal Environment, the proximity of the site to the coast and the moderately strong winds from the south would blow some of the exhaust out over the ocean. For launches during the day, the exhaust would be expected to dissipate relatively quickly. For the Southeastern Atlantic Coastal Environment, launches during the summer and fall may result in exhaust being blown inland, and the high seasonal rainfall would assist in raining out the HCl. Additionally, the prevailing winds during the winter months may disperse the exhaust over the ocean. High solar radiation would also help to disperse the exhaust because strong solar radiation heats air near the ground, causing the air to rise, thus generating large eddies and atmospheric turbulence that promote dispersion. In the Desert-Arid Environment, the high solar radiation would help with dispersion of exhaust at all altitudes, but the flat topography would reduce dispersion tendencies for ground level releases. HCl may be more of an atmospheric problem because of the little rain and humidity in this environment. In the South Central Pacific Coastal Environment, the Santa Ana winds in fall and winter would carry the exhaust to the ocean and would create high mixing heights that would trap most of the exhaust pollutants above the Earth's surface. In other seasons, the exhaust may disperse over land. In the Subarctic Environment, wind would be the main issue. The high winds from June to December would quickly disperse a ground cloud. The high precipitation would also assist in the HCl rainout. In the Ocean or Open-ocean Environment, the exhaust would be carried over the sea in the prevailing wind direction, and the HCl would be rained out. Further discussion and quantification of atmospheric loads is included in Section 5.1. and Appendix A.

5.3.2 Regional Land Resources

The environmental impacts to land resources from the preferred alternative of licensing launches are mainly limited to impacts to soil from the formation of a launch ground cloud (from solid rocket motors) that produces acidic deposition. Soil impacts include temporary increases in available metals and in acidity. Amounts of HCl received by soils depend on the weather conditions and distance from the launch site. In non-saline type soils, increases in conductivity might be expected (e.g., calcium (Ca), potassium (K), sodium (Na), and zinc (Zn)) and decreases in phosphorus (P) and nitrogen as nitrate and nitrogen as ammonia. In saline type soils, increases in Ca, K, Na, Zn, and P might be expected, but not an increase in conductivity. Also in saline type soils, decreases in nitrogen as ammonia, but not nitrogen as nitrate might be expected.[162] It should also be noted that license applicants will be required to comply with all applicable waste disposal regulations including RCRA requirements. Differences among potential local impacts are considered below.

Southeastern Atlantic Coastal Environment. Soils in this environment type tend to be well buffered (ability of a buffer solution to resist pH change upon addition of an acid or a base), and a cumulative decline in pH is not expected. This environment has both saline and non-saline soils.

Desert-Arid Environment. Soils in this environment type tend to be well buffered, and a cumulative decline in pH is not expected.

South Central Pacific Coastal Environment. The surface horizons of soils in this environment type appear to be high in both organic matter content and percent base saturation. High organic matter content and base saturation (extent to which the adsorption complex of a soil is saturated with alkali Earth cations) result in the soil having a high buffering capacity. Therefore, limited impact is expected to the soils due to their high buffering capacity and the fact that the HCl expected from the dry launch system used in this region would be airborne in limited quantities and would be rained out over a limited area.[163]

Subarctic Environment. Soils in this environment tend to be well buffered because they have a high cation exchange capacity with an exchangeable H+ solution to H+ equilibrium of about 23,000:1 favoring H+. Therefore, no long-term measurable changes in soil acidity are expected.

Ocean or Open-ocean Environment. This environment does not contain soils in the path of the atmospheric deposition from the launch combustion products. Deposition to ocean surface waters is discussed below.

5.3.3 Regional Water Resources

Surface water impacts include temporary increases in available metals and temporary increases in acidity. Levels of impacts to surface waters are highly variable spatially and temporally, and depend upon meteorological conditions at the times of launches.[164] Launch-related acid rain is created when fire and/or sound suppression system deluge water evaporates during a launch, scavenges HCl gas from the exhaust, and forms hydrochloric acid droplets. Launch-related acid rain would not be an impact at launch site facilities using a dry launch duct (i.e., no deluge water system). Even with dry launch systems, the presence of coastal aerosols such as mists, fogs, or the marine layer could cause some molecular scavenging of water by HCl to occur. This process could produce acidic deposits, but on a very limited basis as compared to the levels associated with a wet launch system. In the event of an accident during ascent and possibly during an accident on the launch pad, propellant tanks would be ruptured and the propellants would burn explosively. Thus, it is possible for propellants to be spilled directly or released as a burning byproduct into local water resources (e.g., lakes, rivers) or more distant water resources (e.g., ocean). The extent of impacts depends on the type of propellant, the conditions of the accident, and the type of water resource affected. One category of liquid propellant, hydrazine propellants, is acutely toxic to aquatic life.[165] If released from an accident, hydrazine would either be oxidized in the air, would react and possibly ignite with the porous soil, or would form soluble substances in water such as ammonia, methylamine and dimethyl amine and oxides of nitrogen.[166] These substances are toxic and injurious to plant and lower animal life if present in sufficient concentrations. Local impacts would be experienced.

Hydrocarbon propellants such as RP1 (kerosene) would form a film on the surface of the water. Depending on the quantity released and the surface area of the water body, the film could inhibit oxygen from penetrating the water body.[167] The film would dissipate within hours in large water bodies [168] but could adversely affect the aquatic ecology in small water bodies. Cryogens, such as liquid hydrogen and liquid oxygen represent extreme explosion potential. It is expected that the liquids released from an accident would explode. If, however, they are released directly into water, the cold temperatures of the cryogens would locally impact the water temperature. However, the liquid hydrogen and oxygen would rapidly volatilize and overall are not considered to be harmful to the environment.[169] A spill of hydrogen peroxide would be diluted in the water; however, it would be poisonous to certain life forms. Fourteen parts per million of hydrogen peroxide in water kills fish.[cc] Consequently, it would not be expected that gaseous nitrogen tetroxide byproducts would have any long-term impacts on aquatic life.[dd]

A hypergolic propellant such as nitrogen tetroxide is a toxic gas. In water, nitrogen tetroxide would react to produce nitric and nitrous acids. Ocean water is alkaline and would generally rapidly neutralize these acids. Consequently, it is not expected that the nitrogen tetroxide byproducts would have any lasting impacts on aquatic life. Solid rocket propulsion systems containing substances, such as ammonium perchlorate, are designed to burn the propellant completely. However, it is possible that chunks of the ammonium perchlorate in a binder matrix (e.g., PBAN) could fall into water bodies as unburned segments.[170] The toxicity of the ammonium perchlorate is based on its reactivity; ammonium perchlorate is a strong oxidizer and potentially explosive. As an anion it can act as a competitive inhibitor of biochemical reactions, such as iodine transport in the human thyroid.[171] However, it is expected that the ammonium perchlorate in a binder would dissolve slowly in the water with only very local impacts to marine life.[172] Small water bodies would be more adversely affected than large water bodies.

Differences among potential local impacts are considered below.

<u>Mid-Atlantic Coastal Environment.</u> Surface waters in this environment type tend to be well buffered, and a cumulative decline in pH is not expected.

<u>Southeastern Atlantic Coastal Environment.</u> Surface waters in this environment type tend to be well buffered, and a cumulative decline in pH is not expected.

<u>Desert-Arid Environment.</u> No surface watercourses exist in the immediate vicinity of the local environment and therefore no impacts to this surface water resources would occur in this environment type.

[cc] Andrews, David. Advantages of Hydrogen Peroxide as a Rocket Oxidant, Black Knight Symposium.
[dd] Environmental Assessment for NAVSTAR Global Positioning System, Block IIR, and Medium Launch Vehicle III, Department of the Air Force, November 1994.

South Central Pacific Coastal Environment. Water quality data indicate that the surface water bodies in this region have high total hardness with high levels of cations such as Ca, Mn, and Na. In the event that rain water absorbs HCl which might in turn then be deposited on the water, the natural buffering capacity of the streams would result in negligible or no change in water quality.[173]

Subarctic Environment. Based on the buffering capacity and volumes of the surface waters in this environment, small pH changes could result from atmospheric deposition of HCl.

Ocean or Open-ocean Environment. No adverse effects from acid deposition are anticipated from the preferred alternative on the open-ocean environment, because the volume of ocean water and the flushing effect would quickly dilute any pH changes.

5.3.4 Regional Biological Resources

Flora in the vicinity of the launch site may be affected by the launch exhaust products from near-field sources, far-field depositions, or from combustion products associated with catastrophic events. These impacts would be a function of the weather, the behavior of the ground cloud, the location of the biota relative to the diffusing cloud mass, and the type of vehicle launched. At high concentrations, effects on flora could range from injury to leaves or flowers to leaching of nutrients through the leaves. Vegetation changes from repeated near-field deposition include loss of sensitive species, decline in shrub cover, and increasing bare ground. However, affected vegetation would be expected to recover, based on deposition impacts on vegetation from Space Shuttle launches.[174] Impacts to wetlands could also occur from acid deposition depending on how often the wetlands are inundated with water and the amount of water. Wildlife impacts from repeated near-field deposition can include fish kills and occasional mortality of terrestrial fauna. Launches present the potential for acute impacts to fish and wildlife in the vicinity of the launch pad resulting from noise, blast debris, heat, and toxic chemicals (primarily HCl from solid propellants). Chronic impacts could result from subtle alterations in habitat and potentials for bioaccumulation of pollutants that may be released into the environment. However, a study of the impact of ten years of Shuttle launches on the local biota, soil, and water has not borne this out.[175]

Other possible impacts to biological resources could be lighting associated with facilities at the launch site or other launch-related physical disturbances to the environment. For example, endangered sea turtle hatchlings have been disoriented by exterior launch site lighting, moving inland rather than seaward and consequently suffering increased mortality.[176]

Fires and explosions, though highly improbable events, also constitute potential biota-impacting accidents. Specific effects would depend on the location and extent of the accident and the resultant primary effects (changes in noise, air quality, water quality, and thermal surroundings). Fires could begin near the launch site and burn off special habitat unless immediately contained. Subsequent natural re-growth would occur, but could take several years depending on the extent of the fire damage. Fire control measures would reduce this extent. Proven fire fighting methods would be employed in all appropriate situations. Explosions of highly-stable solid rocket motors are highly unlikely, but may occur in rare situations. The environmental impacts would most likely be minimal. For example, preliminary results of biological monitoring after the January 17, 1997 Delta II failure indicate that there were no discernible effects on the scrub jay population and that the overall population of Southeastern beach mice actually increased in areas affected by the explosion.[177]

One concern is that a higher launch rate in the future could produce long term effects on biota not exhibited under the current infrequent launch rate schedules. For instance, even if HCl were neutralized by alkaline soils, an excess of chloride would remain in the soil. This excess may be harmful to plant life over the longer term. However, several factors suggest that significant additive effects on vegetation would not occur at current or future launch sites, including: (1) minimal effects are expected per launch; (2) susceptible plant parts (e.g., leaves, flowers) are short-lived, limiting the number of launches to which they are exposed; and (3) HCl gas dissipates after a launch, and would not accumulate in the area due to the high buffering capacity of the soil. Similarly, several factors suggest that significant additive effects on wildlife would also not occur, including: (1) minimal effects are expected per launch; and (2) no far-field cumulative effects on wildlife were observed to be caused by the 43 Space Shuttle launches over a ten year period.[178] However, high launch rates could displace sensitive bird or waterfowl species in some environments, requiring monitoring for potential effects in the future.

Mid-Atlantic Coastal Environment. Diverse animal species would be expected in this environment type with somewhat less diverse plant species. Many terrestrial and aquatic species may live in this environment. Few plants are able to thrive in the beach communities of this environment type, but more variety may be found in dunes, swales, maritime forests, and marshes. Protected species potentially found in this environment type may include:

Upland sandpipers (*Bartramia longicauda*)
American sandpipers
Piping plover *(Charadrius melodus*)
Gull-billed tern *(Sterna nilotica)*
Wilson's plover *(Charadrius wilsonia)*[179]

While some adverse impacts could be expected in the immediate launch area, local wildlife impacts are anticipated to be minimal and manageable overall due to the infrequency and short duration of launches and the tendency for wildlife to scatter and then return after launches. Impacts on waterfowl populations in this environment might be of potential concern because, as stated earlier, waterfowl are more likely to injure themselves or their young when exposed to sudden noise. Monitoring of waterfowl and bird populations would be appropriate in this environment. NASA has determined that current launch programs in this environment type "are not nearly as intrusive to the plover habitat as predators and recreational use."[180]

Southeastern Atlantic Coastal Environment. Diverse biological species would be expected in this environment type. Examples of sensitive species in the dune and strand communities are herbs with thin leaves and some shrubs with succulent leaves. Shrubs vary in sensitivity, but most grasses and heavily cutinized plants tend to be resistant. Wildlife impacts from repeated near-field deposition might include fish kills and occasional mortality of terrestrial fauna as well as potential impacts to coral reefs. Protected species potentially found in this environment type may include:

Florida Scrub Jay *(Aphelocoma coerulescens coerulescen)*
Eastern Indigo Snake *(Drymarchon corais couperi)*
Gopher tortoise *(Gopherus polyphemus)*
Common Snook *(Centropomus undecimalis)*
American alligator *(Alligator mississippiensis)*
Atlantic loggerhead turtle *(Caretta caretta)*
Atlantic green turtle *(Chelonia mydas)*
Leatherback turtle *(Dermochelys coriacea)*
Eastern indigo snake *(Drymarchon caorais couperi)*
Atlantic hawksbill turtle *(Eretmochelys imbricata)*
Atlantic ridley turtle *(lepidochelys kempi)*
Florida pine snake *(Pituophic malanoleucus)*

Gopher frog *(Rana areolata)*
Florida scrub lizard *(Sceloporus woodii)*
Cooper's hawk *(Accipiter cooperii)*
Bachman's sparrow *(Aimophilia aestivalis)*
Roseate spoonbill *(Ajaia ajaja)*
Dusky seaside sparrow *(Ammospiza maritima nigriscens)*
Florida scrub jay *(Aphelocoma coerulescens)*
Limpkin *(Aramus guaruna)*
Burrowing owl *(Athen cunicularia)*
Swainson's hawk *(Buteo swainsoni)*
Great egret *(Casmerodius melodus)*
Piping plover *(Charadrius melodus)*
American harrier or Marsh hawk *(circus cyaneus)*
Florida prairie warbler *(Dendroica discolor paludicola)*
Little blue heron *(Egretta caerulea)*
Reddish egret *(Egretta rufescens)*
Snowy egret *(Egretta thula)*
Tricolored heron or Louisiana heron *(Egretta tricolor)*
Swallow-tailed kite *(Elnoides forticatus)*
White ibis *(Eudocimus albus)*
Merlin or pigeon hawk *(Falco columbarius)*
Southeastern kestrel *(Falco sparverius sparverius)*
Rothchild's magnificent crane *(Fregata magnificens rothschildi)*
Florida sandhill crane *(Grus canadensis pratensis)*
American oystercatcher *(Haematopus palliatus)*
Worm-eating warbler *(Helmitheros vermivorus)*
Least bittern *(Ixobrychus exilis)*
Black rail *(Laterallus jamaicensus)*
Wood stork *(Mycteria americana)*
Yellow-crowned night heron *(Nyctanassa violacea)*
Black-crowned night heron *(Nycticorax nycticorax)*
Osprey *(Panion haiaetus)*
Eastern brown pelican *(Pelecansu occidentalis)*
Red-cockaded woodpecker *(Picoides borealis)*
Hairy Woodpecker *(Picoides villosus auduboni)*
Glossy ibis *(Plegadis falcinellus)*
American avocet *(Recurvirostra americana)*
Black skimmer *(Rynoochops niger)*
Louisiana waterthrush *(Seiurus motacilla)*
Amercan redstart *(Setophaga ruticiila)*
Least tern *(Sterna anttillarum)*
Caspian tern *(Sterna caspia)*
Roseate tern *(Sterna dougallii)*
Sooty tern *(Sterna fuscata)*
Royal tern *(Sterna maxima)*
Sandwich tern *(Sterna sandvicensis)*
Black whiskered vireo *(Vireio altiloquus)*
Florida panther *(Felis concolor coryi)*
River otter *(Lutra canadensis)*
Bobcat *(Lynx rufus)*

Florida weasel *(Mustela frenata penisulae)*
Florida mink *(Mustela vison lutensis)*
Round-tailed muskrat *(Neofiber alleni)*
Florida mouse *(Peromyscus floridanus)*
West Indian Manatee *(Trichechus manauts latirostris)*
Florida black bear *(Ursus americanus floridansus)*

Flora

Giant leather fern *(Acrostichum daneifolium)*
Blsam torchwood *(Amyris balsamifera)*
Curtis milkweed *(Asclepias curtisssii)*
Ebony spleenwort *(Aspelium platyneuron)*
Black mangrove *(Avicennnia germinans)*
Mosquito fern *(Azolla caroliniana)*
Curtiis reedgrass *(clamovilfa curtissii)*
Grass pink *(Clopogon tuberosus)*
Fragrant wool-bearing cereus *(Cereus eriophours)*
West coast prickly-apple *(cereus gracilis)*
Satinleaf *(Chrysophyllum olivaeforme)*
Coconut palm *(Cocos nucifera)*
Large-flowered rosemary *(Conradina grandiflora)*
Florida white-top sedge *(dichromena floridensis)*
Butterfly orchid *(Encyclia tampensis)*
Wild coco *(Eulophia alta)*
Rein orchid *(habenaria odontopetala)*
Water spider orchid *(Habenaria repens)*
Orchid *(Harrisella porrecta)*
Crested coralroot *(Hexalectris spicata)*
Broad leaved spider lily *(Hymenocllis latifolia)*
Carolina holly *(Ilex amigua)*
Nodding pinweed *(Lechea cernua)*
Foxtail club moss *(Lycopodium alopecuroides)*
Southern club moss *(Lycopodium appressum)*
Slender club moss *(Lycopodium carolinianum)*
Florida malaxis *(Malaxis spicata)*
Boston fern *(Nephrolepis biserrata)*
Adder's tongue fern *(Ophioglossum palmatum)*
Prickly pear cactus *(Opuntia compressa)*
Royal fern *(Osmunda regalis)*
Pepper *(Peperomia humilis)*
Florida peperomia *(Peperomia obtusifolia)*
Lemon vine *(Pereskia aculeata)*
Sward redbay *(Persea borbonia)*
Golden polypody *(phlebodium aureum)*
Rose pgonia *(Pogonia ophioglossoides)*
Shadow witch *(Ponthieva racemosa)*
Whisk fern or fork fern *(Psilotum nudum)*
Red mangrove *(Rhizophora mangle)*
Water spangles *(Salvinia rotundifolia)*

Neclace pos *(Sophora tomentosa)*
Lace-lip ladies tresses *(Spiranthes laciniata)*
Bay cedar *(Suriana marituma)*
Aspidium fern *(Thelpteris interrupta)*
Marsh fern *(Thelypteris palustris)*
Wild pine *(Tillandsia simulata)*
Sea lavender *(Tournefortia gnaphaldes)*
Coastal vervain *(Verbena maritima)*
Tampa vervain *(Verbena tampenis)*
Shoestring fern *(vittaria lineata)*
Netted chain fern *(Woodwardia aerolata)*
East coast coontie *(Zamia umbrosa)*
Orchid *(Zeuxine strateumatica)*[181]

However, local wildlife impacts are anticipated to be minimal and manageable overall due to the infrequency and short duration of launches and the tendency for wildlife to scatter and then return after launches.[182] For example, since 1995, pre-launch and post-launch surveys of nine Atlas launches have been performed at a government launch site in this environment type that has been in use since 1962. No animal or aquatic species mortality has been observed in these surveys. Furthermore, impacts on vegetation are confined to two small areas (approximately 25 to 50 meters wide and 30 to 150 meters in length) immediately adjacent to the two pads.[183]

<u>Desert-Arid Environment.</u> Limited, but in some cases relatively unique, species and habitats would be expected in this environment type. Protected species potentially found in this environment type may include:

Bell's Vireo *(Vireo belli)*
Ferrunginous Hawk *(Bueto regalis)*
Western Burrowing Owl *(Speotyto cunicularia hypugaea)*
Loggerhead Shrike *(Lanius ludovicianus)*
Texas horned lizard *(Phrynosoma cornutum)*
Northern Aplomado Falcon *(Falco femoralis septentrionalis)*
Cooper's Hawk (*Accipiter cooperii)*
Golden Eagle *(Aquila chrysaetus)*
Long-eared Owl *(Asio otus)*
Great Horned Owl *(Bubo virginianus)*
Swainson's Hawk (*Buteo swainsoni)*
Northern Harrier *(Circus cyaneus)*
Prairie Falcon
American Kestrel *(Falco sparverius)*
Harris's Hawk *(Parabuteo unicinctus)*
Short-horned lizard *(Phrynosoma douglassii)*[184]

While some adverse impacts could be expected in the immediate launch area, local wildlife impacts are anticipated to be minimal and manageable due to of the infrequency and short duration of launches, the tendency for wildlife to scatter and then return after launches, and the generally low number of wildlife populations in this environment. Monitoring and mitigation plans would be appropriate, particularly for the desert tortoise.

South Central Pacific Coastal Environment. Diverse biological species would be expected in this environment type. Protected species potentially found in this environment type may include:

Unarmored Threespine Stickleback *(Gasterosteus culeatus williamsoni)*
Tidewater Goby *(Eucyclogobius newberryi)*
California Red-legged frog *(Rana aurora)*
California Brown Pelican *(Pelecanus occidentalis californianus)*
Western Snowy Plover *(Charadrius alexandrinus nivosus)*
California Least Tern *(Sterna albifrons)*
Southern Sea Otter *(Enhydra lutris nereis)*
Harbor Seals *(Phoca vitulina richardsi)*[185]

Observation of plant communities and wildlife at active launch sites in this environment type indicate that plants and wildlife are able to thrive in the extreme, near-field launch area, even under conditions associated with relatively large launch vehicles using water sound suppression systems. Thus, exposures during routine operations are expected to be low and effects on biota are expected to be minor and short-term in this environment type.

Subarctic Environment. This environment may include a rich variety of wildlife, including a broad range of bird and waterfowl species (terrestrial and/or marine-oriented), terrestrial mammals (e.g., bats, hares, squirrels, voles, beaver, fox, otter, bear, and goat), marine animals (e.g., large to small-sized cetaceans and pinniped species), and freshwater and anadromous fish. Protected species potentially found in this environment type may include:

Steller's Eider *(Polysticta stelleri)*
Steller Sea Lion *(Eumetopias jubatus)*
Fin Whale *(Balaenoptera physalus)*
Humpback Whale *(Megaptera novaeangliae)*[186]

It is possible that fish could be impacted by rapid increases of hydrochloric acid from drainage of deluge water in nearby water bodies in this environment type, if water sound suppression systems are used. However, due to the characteristics of water bodies in this environment type (high rainfall/flushing rates, short steep streams with small drainage areas), long term effects to native game and non-game fish in these streams would not be anticipated. However, monitoring of nearby surface water bodies and fish populations would be appropriate.

It is anticipated that most birds would be frightened away by the noise of launches and thus would not come into contact with launch plumes. There are currently no data available about the exact effects exposure to such low levels of hydrochloric acid would have on birds. However, it is possible that birds flying through the launch cloud in this environment type could experience minor eye and respiratory irritation from concentrations of hydrochloric acid. Because of this, monitoring of bird populations would be appropriate.[187]

Overall, minor damage to vegetation and wildlife in the immediate vicinity of the launch pad could occur in this environment type. However, local wildlife impacts are anticipated to be minimal and manageable because of the infrequency and short duration of launches, the characteristics of water bodies in this high rainfall environment, and the general tendency for all wildlife to scatter and then return after launches.

Ocean or Open-ocean Environment. Limited and geographically dispersed biological species would be expected in this environment type. No environmental effects are anticipated from the preferred alternative in the open-ocean environment. The water, atmospheric, and biological resources (including fishing zones) are not expected to be impacted or would be negligibly impacted due to the extreme remoteness of this type of launch environment.[188] Protected species potentially found in this environment type may include:

Whales
- Whale, blue (*Balaenoptera musculus)*
- Whale, bowhead *(Balaena mysticetus)*
- Whale, finback *(Balaenoptera physalus)*
- Whale, humpback *(Megaptera novaeangliae)*
- Whale, right *(Balaena glacialis)*
- Whale, Sei *(Balaenoptera borealis)*
- Whale, sperm *(Physeter macrocephalus)*

Sea Birds
- Petrel, Hawaiian dark-rumped *(Pterodroma phaeopygia sandwichensis)*
- Shearwater, Newell's Townsend's *(Puffinus auricularis newelli)*

Sea Turtles
- Turtle, green sea *(Chelonia mydas)*
- Turtle, hawksbill sea *(Eretmochelys imbricata)*
- Turtle, Kemp's (Atlantic) ridley sea *(Lepidochelys kempii)*
- Turtle, leatherback sea *(Dermochelys coriacea)*
- Turtle, loggerhead sea *(Caretta caretta)*
- Turtle, olive (Pacific) ridley sea *(Lepidochelys olivacea)*[189]

5.3.5 Marine Animal Strike Probability Analysis

Normal operating procedure for ELV flights is the separation and jettison of expended stages, motors, or fairings over the ocean. Reusable launch vehicles are designed so that expended stages return to the launch site, recovery site, or alternate emergency site, land, and are recovered. Thus, this type of LV is not considered further for this analysis.

There is a remote possibility that jettisoned or separated motors, stages or fairings from an LV could strike a marine animal when it enters the ocean during nominal flight operations. The probability of a strike has been approximated using conservative assumptions and simulation analysis with high end CeTAP cetacean density data for the mid-Atlantic Ocean and ship survey data in California waters for the Pacific Ocean. The results of this analysis indicate that there is extremely little chance of an LV component hitting a marine animal. The methodology and results of the analysis are presented in Appendix B. As detailed in the appendix, fewer than 0.5 animal strikes are expected annually, even when all launch activity is summed, and a summation is done across all species over both the Atlantic and Pacific Oceans.

5.4 Socioeconomic Effects of the Preferred Alternative

Development and growth of the commercial launch industry would have a beneficial economic impact. Jobs associated with the commercial launch industry tend to be technology-based and require highly skilled workers with specialized skills and education. The creation of jobs of this caliber has secondary positive economic effects on local communities from increased personal income and the associated tax base. Additional workers create a need for more services, which in turn creates additional jobs. Any impacts associated with workforce increases at a new launch site, including the ability of communities to provide needed infrastructure support (e.g., roads, schools), would be assessed in site-specific NEPA documentation.

The impact on the national economy would probably be small, but is dependent on the success of private ventures. More difficult to predict, but likely, positive impacts are the technology transfer from launch technology to other economic sectors (e.g., manufacturing and consumer goods). If the United States retains a leadership position in launch technology, the country will likely also gain a competitive advantage in other technology-based markets.

5.5 Environmental Justice Effects of the Preferred Alternative

Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low Income Populations, requires federal agencies to identify and address disproportionately high and adverse human health or environment effects of federal programs, policies, and activities on minority and low income populations. A Presidential Memorandum that was issued concurrently with EO 12898 specifically states that NEPA is one of the tools for addressing these issues. "Each agency must analyze the environmental effects, including human health, economic, and social effects, of its actions, including their effects on minority communities and low-income communities, when such analysis is required by the NEPA." The FAA considers environmental justice one of several key areas considered and assessed for impacts during the environmental review process.

Although each community is unique, there are several determination procedures that are common to most environmental justice assessments. It is important that one first identify whether the geographical area being considered qualifies as a low-income or minority-based area. This can be accomplished by analyzing the most recent census data for the subject location (a census block group). The U.S. Bureau of Census maintains census data based upon racial classifications and income levels. The racial data are classified into five racial types: white, black, Hispanic, American Indian/Eskimo/Aleut, and Asian/Pacific Islander. Income data are determined by the percentage of houses within the geographical area of consideration that fall below the mean poverty level (a four person family earning $12,674 or less in 1990). Within each census block group, percentages of minority and low-income communities can then be calculated.

Once the determination is made whether the area in question is populated by low-income or minority individuals, the next determination that must be made is whether the action has disproportionately high and adverse human health or environmental impacts to the community. Environmental justice compliance requires, first, that a determination be made that there are significant and adverse impacts, and, second, that those impacts disproportionately affect the low-income or minority communities. If a determination is made that a particular action would adversely affect a minority or low-income community, the recommended action by the United States Environmental Protection Agency is to have as much community involvement as possible early in the project scoping process. Both EO 12898 and the Presidential Memorandum emphasize the need for public participation and access to information. The Presidential Memorandum states that each federal agency shall provide opportunities for community input in the NEPA process, including identifying potential effects and mitigation measures in consultation with affected communities and improving the accessibility of meetings, crucial documents, and notices.

Specific information about a local community would have to be obtained to fully assess whether environmental justice issues are a concern near a current or future launch site. However, the following subsections suggest possible populations of concern for each generic environment. These populations should be analyzed for disproportionate environmental justice impacts during the environmental review for licensing launch operators. Because this analysis assumes that the preferred alternative would result in *positive* socioeconomic effects, including maintaining or increasing current employment levels in the U.S. launch industry, it is assumed that these positive effects would at a minimum not produce disproportionate *negative* impacts on minority racial, ethnic, or economically-disadvantaged populations.

<u>Southeastern Atlantic Coastal Environment.</u> Environmental justice populations of concern that may live in communities in the southeastern Atlantic coastal environment include Native Americans, Hispanic Americans, African Americans, and economically-disadvantaged populations.

<u>Southwestern Desert-Arid Environment.</u> Environmental justice populations of concern that may live in communities in the southwestern desert-arid environment might include Native Americans, Hispanic Americans, African Americans, and economically-disadvantaged populations.

<u>South Central Pacific Environment.</u> Environmental justice populations of concern that may live in communities in the south central Pacific environment might include Native Americans, Hispanic Americans, Asian Americans, African Americans, and economically-disadvantaged populations.

<u>Subarctic Environment.</u> Environmental justice populations of concern that may live in communities in the subarctic might include Native Americans and economically-disadvantaged populations.

<u>Ocean or Open-ocean Environment.</u> Environmental justice populations of concern that may live in communities in the ocean environment include international minority ethnic and racial populations and economically-disadvantaged populations.

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6. Potential Impacts of the More Environmentally-Friendly Propellant Combinations Alternative

In general, because the proposed alternative of preferentially licensing more environmentally-friendly propellant LVs for launches results in less HCl, Al_2O_3, NO_x, and Cl emissions and less overall launches in the U.S., potential effects in the local and global climate/atmosphere, local land resources, local water resources, local biological resources, and on marine species in the Atlantic and Pacific Oceans, would be correspondingly reduced across all environment types. Socioeconomic effects would be negative, as a result of the anticipated exodus of launches utilizing only solid propellant in the troposphere and stratosphere to outside the U.S.

6.1 Potential Environmental Impacts to the Atmosphere of the More Environmentally-Friendly Propellant Combinations Alternative

Potential impacts to the atmosphere from this alternative were examined in the troposphere and stratosphere. No change from this alternative was estimated relative to the preferred alternative for effects in the mesosphere and ionosphere, because the alternative does not affect emissions in those regions of the atmosphere.

As stated earlier in the description of this alternative in Section 2, air emissions from LVs are determined mainly by propellant type. Environmentally harmful chemical species emitted to the atmosphere vary by the type of propellant used. For example, all propellant systems, except those using purely LO_x-hydrogen systems, produce CO_2, which is a greenhouse gas. Greenhouse gas emissions in the troposphere and stratosphere are of concern because they contribute to global warming by trapping re-radiated energy in the atmosphere (e.g., water vapor, carbon dioxide, methane, nitrous oxide, ozone, chlorofluorocarbons, hydrolfluorocarbons, and perfluorinated carbons). Hybrid and LO_x-RP1 propellant systems produce more CO_2 than solid propellant systems, however, they emit less NO_x than systems using hypergolic propellants. Only solid rocket motors (SRMs) produce tropospheric and stratospheric emissions of HCl and Al_2O_3. HCl is a toxic gas, which is defined by EPA as a Hazardous Air Pollutant. Al_2O_3 is a particulate that can serve as a site for atmospheric reactions depleting ozone. Emissions of HCl and Al_2O_3 are perceived as more significant, immediate environmental threats than the greater amount of CO_2 emissions produced by hybrid and LO_x-RP1 propellant systems (see Appendix A).

Thus, for this analysis, the alternative option of "More Environmentally-Friendly Propellant Combinations" was defined as consideration of vehicles that produce less harmful tropospheric and stratospheric air emissions of HCl and Al_2O_3 for preferential licensing. Because these emissions are clearly linked to a single propulsion system (i.e., SRMs), an alternative to the preferred alternative is to preferentially license LVs using no SRMs or combinations of SRMs and liquids in the troposphere or stratosphere, excluding LVs only powered by SRMs in the troposphere or stratosphere. While it may be environmentally preferable to limit all SRM usage, this alternative is not feasible because current technology requires a combination of liquids, cryrogenics, and SRMs to launch an LV into geosynchronous orbit. Therefore, preferentially licensing LVs that do not utilize SRMs would exclude all larger, three-stage GEO LVs. Furthermore, conclusive data and analysis regarding the specific impacts of emissions from multi-propellant or hybrid propulsion systems currently do not exist. Because the environmental impacts related to emissions from LVs with multi-propellant or hybrid propulsion systems have not been adequately characterized at this time, this analysis relies on existing, available data on emissions from current propulsion systems. Ongoing U.S. Air Force and industry research in this area may alter the future understanding of the cumulative atmospheric impacts of multi-propellant propulsion systems and the relative atmospheric impacts of these different systems.

Preferentially licensing those LVs that are not solely propelled by SRMs would reduce the total number of U.S. licensed launches projected from 2000 through 2010 to 189. The number of launches using liquid, liquid/solid, or hybrid propellant systems is assumed to remain the unchanged under this alternative. Thus, the total number of FAA-licensed launches in the U.S. (i.e., programmatic launches) would decrease substantially under this alternative. It was assumed that the decrease in U.S. licensed launches using only solid propellants would be compensated for by an increase in these launches elsewhere in the world.

Again, as stated earlier, HCl emissions from SRMs are of primary concern because of the large quantity released and because HCl is a source of atmospheric chlorine. Before the HCl can deplete ozone, it must be released from its chemical bond to the hydrogen. This occurs by photolysis which is the breakdown of a molecule by light. Some of the HCl gets mixed into the troposphere and is rained out before the photolytic reaction occurs, therefore, reducing some destruction of ozone by Cl. Beside gases, SRMs release particulates, Al_2O_3, soot, and ice. Attempts to determine the distribution and effect on ozone depletion of Al_2O_3 have been limited and therefore the current models are based upon homogenous gas phase chemistry. Such particulates act as a site for the ozone depleting reaction, but the significance of this role is unclear. Heterogeneous chemistry (which accounts for particulates, plume temperature and afterburning of fuel-rich exhaust) is not included in this PEIS, due to limited data and modeling available to date. However, future analysis of launches using heterogeneous chemistry could alter the understanding of potential impacts of launches on stratospheric ozone-depletion.

The specific HCl input to the stratosphere from launch vehicle exhaust can be estimated if the HCl amount and its time-dependent release along the ascent are known. Using the number of launches estimated in Section 2.0, but eliminating all launches using solely solid propellant systems in the troposphere and stratosphere, the emission load of HCl in the stratosphere for all U.S. licensed launches from 2000 through 2010 (a period of 11 years) is approximately 1,787 tons and additional free Cl load is 24 tons. This averages to approximately 165 tons of HCl and Cl load to the stratosphere from U.S. licensed launches per year. (See Appendix A, Emission/Afterburning Products and Loads for a detailed methodology determining numbers and emissions loads.) In comparison, under the preferred alternative, the emission load of HCl in the stratosphere for all U.S. licensed launches from 2000-2010 is approximately 2,292 tons and additional free Cl load is 31 tons. This averages to approximately 211 tons of HCl and Cl load to the stratosphere from U.S. licensed launches per year.

Accidents on the launch pad. Emissions of concern resulting from potential accidents on the launch pad would be reduced under this alternative because LVs using solid propellant systems would no longer be licensed. Thus, open burning of all solid propellants would not be an issue, thereby avoiding the potential for a release of approximately 3,200 kg (3.5 tons) of HCl emissions; 3,520 kg (3.9 tons) of CO_2 emissions; 2,720 kg (3 tons) of CO emissions; 6,434 kg (7 tons) of Al_2O_3 emissions; and 550 kg (0.6 tons) of NO_x emissions. (These emission estimates are based on the CASTOR 120™ boosters and approximately 49,033 kg (108,100 lb) of propellant; these avoided emissions may be higher with vehicles with larger solid rocket motors.) Furthermore, the potential for HCl to combine with moisture in the air and form hydrochloric acid during an accident would also be avoided. Similarly, accident-related excess CO and NO_x emissions could also potentially impact the air quality or local acid rain in the area of a launch accident for that day, especially if the area is nonattainment and does not meet the National Ambient Air Quality Standards for CO, NO_x or ozone.

Accidents where a flight safety system is activated may result in the burning of remaining propellant in the atmospheric layer where the termination occurs. If the accident occurs in the troposphere, all of the propellant may burn. Emissions from such accidents, especially CO_2, may be greater than an accident on the launch pad and may affect global warming. However, this would be insignificant as compared to CO_2 produced from natural processes in the ocean and from anthropogenic sources.[190] For additional discussion on the potential impacts of launches on global warming please refer to Section 5.1.2. Thus, under this alternative, potential emissions from an accident where a flight safety system is activated and solid propellant is consumed would be avoided for a subset of launches that are assumed would no longer occur in the U.S.

6.2 Noise Effects of the More Environmentally-Friendly Propellant Combinations Alternative

The preferred alternative was not found to be associated with significant noise impacts. The potential noise impacts associated with the more-environmentally friendly alternative could be even less than what is expected with the preferred alternative. This alternative would reduce the impact of launch noise in the aggregate because the number of licensed launches from within the continental United States would be greatly reduced.

6.3 Land Resources Effects of the More Environmentally-Friendly Propellant Combinations Alternative

Implementing the "more environmentally-friendly propellant combinations" alternative would reduce impact on the soils from licensed launches in the vicinity of launch pads at U.S. launch sites. Space Shuttle and other government launches would still have an impact on soil pH. However, the cumulative effects would not be as great due to fewer licensed launches involving only solid propellant. The more environmentally-friendly propellants would not use solids and therefore the impacts caused by the ground cloud to the local vegetation and soils would not be as significant. This alternative would reduce the impact on land resources because the number of licensed launches from within the continental United States would be greatly reduced.

6.4 Water Resources Effects of the More Environmentally-Friendly Propellant Combinations Alternative

The prospect of additional local water impacts near a launch site from licensed launches would be reduced. Additionally, coastal waters, that could be affected in the event of an accident, would experience reduced impacts. This alternative would reduce the impact on water resources because the number of licensed launches from within the continental United States would be greatly reduced.

6.5 Biological Resources Effects of the More Environmentally-Friendly Propellant Combinations Alternative

Vegetation changes from the ground cloud at launch would be reduced as well as wildlife impacts from launch activities. However, the increased demand for launch sites could lead to construction of launch sites outside the U.S.[191] These launch sites could potentially have a significant impact on biodiversity if they are sited on or near endangered or biologically fragile ecosystems (i.e., rain forest, habitats of endangered species). The U.S. has a history of operating launch sites while effectively protecting native species. For example, Kennedy Space Center manages 140,000 acres of protected beach, wetland, and sub-tropical ecosystems with 23 threatened or endangered species living in the environs. Finally, the probability of jettisoned ELV sections (e.g., spent SRMs, payload fairings) making direct contact with a marine species would remain remote. This alternative would reduce the impact on biological resources because the number of licensed launches from within the continental United States would be greatly reduced.

6.6 Socioeconomic Effects of the More Environmentally-Friendly Propellant Combinations Alternative

Development and growth of the commercial launch industry would have a beneficial economic impact; limiting this development and growth by preferentially licensing a subset of LVs would reduce the magnitude of this beneficial impact relative to the preferred alternative.

6.7 Environmental Justice Effects of the More Environmentally-Friendly Propellant Combinations Alternative

Because this is a programmatic EIS, analysis of environmental justice effects of this alternative are general and not site-specific in nature. Thus, environmental justice effects within the scope of this analysis are related to the socioeconomic effects. Because this analysis assumes that this alternative would result in *positive* socioeconomic effects (although less relative to the preferred alternative), including maintaining or increasing current employment levels in the U.S. launch industry, it is assumed that these positive effects would at a minimum not produce disproportionate *negative* impacts on minority racial or low-income populations.

7. Potential Impacts of the No Action Alternative

The no action alternative would negatively impact the national security and foreign policy interests of the United States. Some U.S. government payloads have been launched by the U.S. commercial launch industry. Therefore, if access to licensed launches is not available, the overall limit in available capacity could conceivably impact the U.S. government's ability to launch needed payloads and thereby negatively affect programs that rely on access to space. Additionally, parties that had planned to launch from U.S. launch sites would be forced to find alternatives, potentially exposing sensitive technologies to countries with competing economic and security interests.

Under the no action alternative it is assumed the same number of worldwide commercial launches would take place. However, were the FAA to cease issuing licenses for launches by U.S. companies, the launches would take place on foreign-owned LVs. Without access to licensed launches in the United States; it is likely that other countries with existing launch programs (e.g., France, Russia, China, Canada) would substantially expand their programs to accommodate the excess demand. It is possible that other countries would initiate commercial launches resulting in no net decrease in the environmental impact to the global environment.

7.1. Potential Environmental Impacts to the Atmosphere of the No Action Alternative

It is possible that if no licensed launches could take place from the U.S., then fewer LVs would be launched overall worldwide (unless existing foreign launch programs could expand rapidly to accommodate increased launch requirements). This would result in an overall decrease globally of launch emissions that potentially affect the atmosphere.

However, based on the comparison of capacity and propulsion systems, the transfer of launches from U.S. LVs to foreign LVs could cause an increase in atmospheric emissions overall. Local effects, such as acid rain and tropospheric ozone would happen outside the U.S. However, global warming potential and stratospheric ozone depletion would remain essentially the same based on an equal number of launches. In a similar manner, any potential impacts to the F layer of the ionosphere would occur regardless of where an LV was launched. This alternative would reduce the impact on atmospheric resources because the number of licensed launches from within the continental United States would be greatly reduced.

7.2. Noise Effects of the No Action Alternative

The prospect of noise impacts and sonic booms from licensed launches at current or future licensed U.S. launch sites would be reduced.

7.3. Land Resources Effects of the No Action Alternative

If no licensed launches occurred, there would be no impact on the soils in the vicinity of launch pads at U.S. launch sites. Space Shuttle and other government launches would still have an impact on soil pH, but the cumulative effects from these launches, absent the licensed launches, would not be as great. This alternative would reduce the impact on land resources because the number of licensed launches from within the continental United States would be greatly reduced.

7.4. Water Resources Effects of the No Action Alternative

The prospect of additional local surface and groundwater impacts near a launch site from licensed launches would be eliminated. Additionally, coastal waters, and associated wetlands, and coral reefs that could be affected in the event of an accident, would no longer be potentially impacted. This alternative would reduce the impact on water resources because the number of licensed launches from within the continental United States would be greatly reduced.

7.5. Biological Resources Effects of the No Action Alternative

Vegetation changes from the ground cloud at launch would be reduced as well as wildlife impacts from launch activities. However, the increased demand for launches could lead to construction of launch sites outside the U.S.[192] These launch sites could potentially have a significant impact on the world-wide biodiversity if they are sited on or near endangered or biologically fragile ecosystems (i.e., rain forest, habitats of endangered species). The U.S. has a history of operating launch sites while effectively protecting the native species at the same time. For example, Kennedy Space Center manages 140,000 acres of protected beach, wetland, and sub-tropical ecosystems with 23 threatened or endangered species living in the environs. The probability of jettisoned ELV sections (e.g., spent SRMs, payload fairings) making direct contact with a marine species would remain remote. This alternative would reduce the impact on biological resources because the number of licensed launches from within the continental United States would be greatly reduced.

7.6. Socioeconomic Effects of the No Action Alternative

The no action alternative would have negative socioeconomic impacts by forcing all payloads currently planned for licensed launch in the U.S. to use foreign launch vehicles. As a result, U.S. jobs might be lost to foreign entities to support their launch activities and programs. It is also *possible* that U.S. telecommunications companies and other U.S. space users could be given lower priority in launching satellites, if foreign entities find a market advantage in preferentially launching their own satellites. This in turn could create a potential for scheduling problems and loss of competitiveness for the U.S. in the global technology market.

The U.S. economy might not enjoy the full potential benefits of high-technology jobs or multi-billion dollar revenues derived from the commercial launch industry. Companies directly involved in providing licensed launch services would no longer be able to operate in that capacity and would be significantly affected. Companies that produce rocket engines or vehicle components could also experience a decline in revenue. The impact to hardware producers could be less severe than for service providers because: (1) the revenue stream from continued military and other government launches would likely continue; and (2) the opportunity for sales of propulsion units and vehicle components overseas could improve because foreign launch providers would need more vehicles to meet the demand from the increase in U.S. payloads seeking their launch services.

Closing the private launch sector would both foreclose potential domestic economic benefits and reduce U.S. international competitiveness. If technological advances were achieved during the development and use of foreign LVs, foreign enterprises would gain further advantages in marketing these new goods and services. Thus, foreign economies could possibly be stimulated, while the U.S. would lag behind, both economically and technologically in this market.

7.7. Environmental Justice Effects of the No Action Alternative

Because this is a programmatic EIS, analysis of environmental justice effects of the no action alternative must be general and not site-specific in nature. Thus, environmental justice effects within the scope of this analysis are related to the socioeconomic effects noted in the previous subsection. Because the no action alternative could have negative socioeconomic impacts that may result in a loss of U.S. jobs to foreign entities, it is possible that economically-disadvantaged or minority ethnic or racial populations may suffer some disproportionate affects of these job losses.

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8. POTENTIAL CUMULATIVE IMPACTS

This section analyzes the cumulative impacts of licensed launches combined with all other launches worldwide. All other launches, or non-programmatic launches, include U.S. government launches, foreign commercial launches, and foreign government launches. The emissions loads from all launches to the troposphere, stratosphere, mesosphere and ionosphere will be evaluated. The cumulative impacts on land, water, and biological resources are highly dependent on site-specific characteristics, and therefore are not addressed in this PEIS.

This PEIS, as stated in the definition of the preferred alternative, assesses the potential impacts of 261 licensed (programmatic) launches between 2000-2010. The FAA has estimated that worldwide commercial launches would be 456 between 2000-2010 (excludes licensed launches from U.S. government facilities). Approximately 220 additional commercial launches (non-programmatic) would be launched at foreign launch sites. Other non-programmatic launches, such as U.S. government launches and foreign government launches, have been estimated from various sources (See Appendix A) to be 354 and 326 launches, respectively. This results in a total of 680 government launches between 2000-2010. For the purpose of this PEIS in evaluating cumulative impacts, it is estimated that there would be 1,136 launches worldwide, including programmatic and non-programmatic, between the years 2000-2010. (See Appendix A for further information.)

Preferentially licensing LVs that are not solely propelled by SRMs would reduce the total number of U.S. licensed launches projected from 2000 through 2010 to 189. The number of launches using liquid, liquid/solid, or hybrid propellant systems was assumed to remain unchanged under this alternative. Thus, the total number of FAA-licensed launches in the U.S. (i.e., programmatic launches) would decrease substantially under this alternative. It was assumed that the decrease in U.S. licensed launches using only solid propellants would be compensated for by an increase in these launches elsewhere in the world. Under the no action alternative, there would be no licensed launches in the U.S.

Many studies have been done on the cumulative environmental effects of launches worldwide. The American Institute for Aeronautics and Astronautics convened a workshop to identify and quantify the key environmental issues that relate to the effects on the atmosphere of launches. The conclusion of the workshop, based on evaluation of scientific studies performed in the U.S., Europe, and Russia, was that the effects of LV propulsion exhaust emissions on stratospheric ozone depletion, acid rain, toxicity, air quality, and global warming were extremely small compared to other anthropogenic impacts. The workshop recommended that further analysis needed to be done on the effects of LV propulsion on the atmosphere to account for heterogeneous chemistry (i.e., to better account for particulates, aerosols, soot and ice emissions).

8.1. Potential Environmental Impacts in the Atmosphere

8.1.1. Troposphere

The main cumulative impacts to the troposphere would result from the impacts of the emissions of HCl and NO_x during the LV's ascent. NO_x is a tropospheric ozone precursor. U.S. LVs employed for licensed launches generally do not use hypergols in the first stage and therefore emit very small quantities of NO_x. Therefore, the impacts of the NO_x emissions would be insignificant. Table 8-1 summarizes the world total emission loads to the troposphere. The carbon monoxide produced by the LV's propulsion systems is assumed to react with oxygen in air to produce carbon dioxide in the high temperatures of the exhaust plume. The impacts of these specific emissions are discussed below.

Overall, the cumulative impact of all of these emissions loadings is relatively insignificant compared with industrial and natural emissions loadings to the troposphere. As the table shows, HCl and Cl emissions to the troposphere for non-programmatic launches are more than six times greater than those from programmatic launches.

TABLE 8-1
SUMMARY OF PROGRAMMATIC AND NON-PROGRAMMATIC EMISSION LOADS FROM LVs TO THE TROPOSPHERE (TONS) FROM 2000-2010

	HCl	Al_2O_3	CO_2	H_2O	N_2	Cl	NO_x	CO
Programmatic US Licensed	2,292	4,147	25,365	11,771	0	31	2,946	0
Non-Programmatic US Government Launches	13,079	23,667	37,512	32,252	0	174	18,666	0
International (nonU.S) Commercial Launches	835	1,509	11,380	8,090	0	11	18,110	0
Foreign Government Launches	1,661	3,006	18,990	14,146	0	22	33,468	0
Total Non-Programmatic	15,575	28,182	67,882	54,488	0	207	70,244	0
Total Programmatic and Non-Programmatic	**17,867**	**32,329**	**93,247**	**66,259**	**0**	**238**	**73,190**	**0**

Acid Rain. Solid rocket motors produce HCl in the exhaust plume that is released into the troposphere. Although local acid rain from LV exhaust is common, the global contribution of LV exhaust to acid rain is very small. On a global scale, HCl produced by all programmatic/non-programmatic launches is less than 0.0007 percent of the total HCl production from the oceans alone and is less than 0.11 percent of anthropogenic sources, such as coal burning power plants. It is estimated that launching nine Space Shuttles and six Titan IVs each year would deposit the same amount of HCl into the troposphere as is produced by the Atlantic Ocean each year in an area of the ocean represented by a square less than 30 miles on each side.[193]

8.1.2. Stratosphere

In the stratosphere, cumulative impacts of launches could *potentially* affect global warming and depletion of the stratospheric ozone layer because chemicals are emitted during launch activities that play a role in these atmospheric conditions. However, the cumulative impact on global warming from launches is insignificant when compared to other industrial sources. Additionally, the cumulative impact on stratospheric ozone depletion from launches is far below and indistinguishable from the effects caused by other natural and man-made causes. Ongoing research in this area indicates that ozone depletion from LV exhaust is limited spatially and temporally, and that these reactions do not have a globally significant impact on stratospheric chemistry.[194] Table 8-2 summarizes both programmatic and non-programmatic emission loads to the stratosphere; note that the load to the stratosphere would be the same as the load to the troposphere (as shown in Table 8-1) because the residence time is assumed to be the same (60 seconds) and the propellant type used is assumed to be the same.

TABLE 8-2
SUMMARY OF EMISSION LOADS FROM PROGRAMMATIC AND NON-PROGRAMMATIC LAUNCHES TO THE STRATOSPHERE (TONS)

	HCl	Al_2O_3	CO_2	H_2O	N_2	Cl	NO_x	CO
Programmatic								
US Licensed	2,292	4,147	25,365	11,771	0	31	2,946	0
Non-Programmatic								
US Government Launches	13,079	23,667	37,512	32,252	0	174	18,666	0
International Commercial Launches	835	1,509	11,380	8,090	0	11	18,110	0
Foreign Government Launches	1,661	3,006	8,990	14,146	0	22	33,468	0
Total Non-Programmatic	15,575	28,182	67,882	54,488	0	207	70,244	0

8.1.2.1.Global Warming

The cumulative impact on global warming from launches is insignificant compared to other industrial sources (e.g., energy generation using fossil fuel) and activities (e.g., deforestation and land clearing). The U.S. licensed launch emissions load of CO/CO_2 to the troposphere, stratosphere, and mesosphere is only about 1/3 of the non-programmatic emissions load. However, even when accounting for both programmatic and non-programmatic (cumulative impact) CO/CO_2 loads combined, it is infinitely small compared to emissions loads from other industrial sources just in the United States. As Table 8-3 indicates, the amount of CO/CO_2 emissions load from all LVs worldwide over the time period 2000-2010 is 0.0005 percent of CO/CO_2 emissions from U.S. industrial sources in one year.

TABLE 8-3
COMPARISON OF EMISSIONS LOADS OF CO/CO_2 TO THE TROPOSPHERE AND STRATOSPHERE

Emissions Sources	CO/CO_2 Emissions in tons
Programmatic (US Licensed Launches) from 2000-2010	50,730
Non-Programmatic from 2000-2010	135,764
Other Industrial Sources in the United States	150,200,000,000 for four years 37,550,000,000 for one year

*Source: USEPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1994.

8.1.2.2.Ozone Depletion

The cumulative impact on stratospheric ozone depletion from launches is far below and indistinguishable from the effects caused by other natural and man-made causes. This PEIS estimates impacts from much smaller LVs than the Space Shuttle, thus air impacts from the Space Shuttle provide a conservative upper bound for comparison.

As Table 8-4 indicates, the emission loads of Cl (both HCl and Cl ion) from both programmatic and non-programmatic launches from 2000-2010 account for only 1.1 percent of the industrial Cl load from the U.S. over the period 2000-2010. The vast amount of the Cl load from LVs is as HCl which does not readily breakdown into the ozone depleter Cl. Also, the HCl in the troposphere is usually quickly removed. The emission loads of Cl from launch activities is also minimal in comparison to the 400,000 tons of inorganic chlorine created annually by photolysis of historical reservoirs of CFCs.

Almost all of the studies to date on ozone depletion from LVs are based upon homogenous gas phase chemistry which does not address the effects from particulates and aerosols released during ascent. There are no existing models which can predict the effects from particulates and aerosols on ozone depletion caused by LVs. Future analysis of launches using heterogeneous chemistry could significantly alter the understanding of cumulative impacts of launch emissions on stratospheric ozone-depletion. There is some evidence that particulates may play a larger role in ozone depletion reactions than has currently been demonstrated. If this is the case, assuming only homogenous gas phase chemistry (i.e., no effects from particulates or aerosols) would underestimate the amount of ozone depletion actually occurring as a result of emissions from LV launches.

TABLE 8-4
COMPARISON OF EMISSIONS LOADS OF CHLORINE (HCl AND FREE Cl) IN THE TROPOSPHERE AND STRATOSPHERE FROM 2000-2010

Emissions Sources	Cl Emissions in tons
Programmatic (US Licensed Launches) from 2000-2010	4,646
Non-Programmatic from 2000-2010	31,564
Other Industrial Sources in the United States	3,300,000

* Source: Scientific Assessment Paper 1994 data is 300,000 tons/year from 1985-1992. Assumed rate would stay the same for 2000-2010.

8.1.3. Mesosphere

Due to the brief amount of time LVs spend passing through the mesosphere, there are no cumulative impacts predicted to the mesosphere.

8.1.4. Ionosphere

Water, CO_2, and atomic hydrogen exhaust products from LVs have been found to have a temporary effect on electron concentration in the F layer of the ionosphere. The temporary effect is a “hole” caused by a rapid charge-exchange reaction between the exhaust products and the ambient atomic oxygen ions in the F layer. Not all launches cause a “hole” in the F layer of the ionosphere. Rather, this effect is dependent on the location of the final parking orbit of the vehicle. The more LVs that are launched, the greater the potential for creating “holes” in the ionosphere, resulting in a cumulative impact on the ionosphere from programmatic and non-programmatic launches. Based on the limited available data indicating that this effect is temporary, however, the cumulative impacts to the ionosphere are considered minute.

8.1.5. Accidents

When an accident occurs near the launch pad or a launch anomaly results in using a flight safety system, there is a cumulative effect on air quality, potential global warming, and stratospheric ozone depletion. Accidents near the launch pad have a more local environmental impact, whereas releases from vehicle destruct via the flight safety system have a potential cumulative global impact. Emissions from the open burn of solid propellant include the following: HCl, CO, CO_2, Al_2O_3, and NO. For vehicles using a liquid hydrocarbon propulsion system (e.g., LO_x-RP1) or a hybrid propellant (e.g., solid/LO_x), CO_2 would be the largest emissions source of concern. The open burn of hypergolic propellants would result in the formation of NO_2 and NO.

For accidents that occur in the stratosphere, HCl and NO_x emissions could potentially contribute to stratospheric ozone depletion, while CO_2 emissions could potentially contribute to global warming. These effects of an accident on ozone depletion and global warming would be greater with a larger LV. Although on a cumulative basis the likelihood of accidents occurring increases as the number of launches increases, accidents involving launch vehicles are relatively uncommon events primarily because launches of these vehicles are infrequent events especially as compared to other traditional modes of transportation. It should be noted that the FAA typically assumes a failure probability ranging from 10% to 31% in evaluating operations during the license review process. Therefore, the overall cumulative impacts from accidents are insignificant as compared with other emission sources.

8.2. Potential Cumulative Noise Impacts

In general, the potential cumulative impacts of noise from launches are expected to be local rather than global. However, an important possible cumulative noise impact might be changes in the migrating route and habitat choice of certain marine animals exposed to repeated occurrences of sonic booms from LVs.

8.3. Potential Cumulative Impacts to Local Environments

Any potential for cumulative impacts to local environments is beyond the scope of this PEIS and would be considered in site-specific documentation.

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9. MITIGATION

This section addresses broad mitigation measures that may be implemented to prevent or reduce environmental effects associated with the preferred alternative. A complete analysis of specific mitigation measures would be addressed in site-specific environmental documentation required for the FAA licensing. In order to ensure that mitigation measures are effective and in compliance with applicable regulatory requirements, appropriate monitoring would need to be conducted at individual launch sites, such as water sampling and analyses, storm water pollution prevention plans and permits, archeological surveys and avoidance of areas with historical artifacts, and biological species surveys by specialists to monitor health and numbers of biological species of concern. Another mitigation activity is the requirement that all launch sites comply with the permit conditions imposed by regulatory authorities. Research is continuing in several areas vital to mitigating potential environmental impacts of LVs, including analysis of the relative merits and impacts of different propulsion systems. For example, research is ongoing into the performance capabilities and environmental attributes of scavenged propellants, neutralized propellants, solution propellants, and minimum signature propellants. As additional data on this topic become available, this information should be used to implement appropriate programmatic mitigation measures. Mitigation measures would only be employed if they are found to be consistent with existing safety criteria.

Examples of mitigation measures are described below.

9.1. Noise

Research and guidelines regarding noise harassment and injury to threatened or endangered species are evolving. Launch personnel responsible for environmental health and safety should keep abreast of advances in this area, and take active measures to avoid levels established as inducing behavior modification or injury (e.g., certain sea state conditions may be associated with less noise impacts, as well as certain slower speeds). Possible actions to mitigate the effects of noise at launch sites include:

- Orientating the flame bucket away from sensitive receptor areas.
- Using a deflector sheet on the flame bucket.
- Constructing blast fences around the launch site perimeter.
- Restricting launches to optimal seasons (e.g., launching only during non-nesting or non-migratory seasons, depending on the species of concern).
- Restricting launches to optimal times during the day (e.g., preferably mid-day).
- Planting tall and fast-growing trees around the perimeter of the launch site (e.g., poplar trees).
- Constructing berms along roadways.
- Using lower engine power levels at liftoff, as appropriate.
- Coordinating with U.S. Fish and Wildlife and National Marine Fisheries Service (NMFS) personnel regarding appropriate local activities and monitoring of sensitive species.

9.2. Water Quality

Possible actions to mitigate the effects on water quality at launch sites include:

- If surface or ground water is to be withdrawn for fire protection, personnel deluge purposes, noise mitigation, or for potable water, studies may be undertaken to ensure the reservoir has an adequate capacity.
- Preparing spill contingency plans that are updated as frequently as needed.
- Containment structures can be constructed around storage facilities to prevent a leak from impacting surface or ground water.
- Contoured land or catchment basins can be put in place to collect excess water from flame suppression or noise suppression activities to prevent runoff into bodies of water.
- Recycle or reuse water generated and used on site.
- Marine pollution abatement measures may include: deployment of booms, use of dispersion chemicals, collection of debris, and implementation of a monitoring program.

9.3. Air Quality

Possible actions to mitigate the effects on air quality at launch sites include:

- Using environmentally-friendly propellants, as feasible.
- Launching in optimal weather and wind conditions to maximize the rate of dissipation of the ground cloud while minimizing the potential impacts to sensitive receptors.
- Participating in emissions banking/trading programs.

Research is continuing in several areas vital to mitigating the potential air impacts of launches. As additional information becomes available regarding currently unresolved research questions, this information should be used to implement appropriate air quality mitigation measures. Examples of current unresolved research questions include: (1) the influence of local stratospheric meteorology in ozone depletion related to LV emissions; (2) size distributions and relative influence of alumina versus soot emissions; (3) U.S. LO_x/kerosene propellant systems ozone loss mechanism; (4) emissions and potential ozone-depleting differences between U.S. and Russian LO_x/kerosene motors; and (5) impacts from emissions from pure (no SRM) LO_x/kerosene LV propellant systems.[195]

9.4. Solid and Hazardous Waste

Possible actions to mitigate the effects of solid and hazardous wastes at launch sites include:

- Taking advantage of all pollution prevention opportunities, and implementing an active pollution prevention plan and reward system.
- Implementing a proactive recycling program for solid and some hazardous wastes to minimize the amounts generated.
- Purchasing environmentally-friendly products whenever possible.
- Maintaining appropriate site-specific clean-up materials in accordance with spill prevention and preparedness procedures (e.g., pH neutralizers).
- Developing a comprehensive Environmental Management System consistent with ISO 14000 guidelines.

9.5. Cultural and Historical Resources

The most important mitigation action to protect cultural and historical resources is to restrict activities and disturbances at launch sites, as much as is feasible, to limited areas in order to maintain near-natural conditions on as much of the site as possible. In addition, consultation with appropriate state historic preservation offices, tribal historic preservation offices, local communities, and impacted populations should be conducted to identify and further mitigate possible effects on cultural and historical resources. Specific mitigation actions should include the following:

- Whenever possible, avoid launching in culturally or historically sensitive areas.
- Relocate resources, if possible and approved by stakeholders and public authorities.
- Protect resources from launch impacts with blast fences, enclosures, and other physical control measures.
- Coordinate with the state historic preservation office, tribal historic preservation offices, and other local authorities, as appropriate and meet proactively with members of the public.

9.6 Biological Resources

The most important mitigation action to protect biological resources is to restrict activities and disturbances at launch sites, as much as is feasible, and to limited areas in order to maintain near-natural conditions on as much of the site as possible. Generic mitigation measures should also include proper containment of all chemicals and an adequate spill preparedness program, including effective emergency and disaster plans to minimize the effects of accidents. Specific mitigation measures to protect biological resources at launch sites might also include the following:

- Relocating endangered or threatened animals.
- Banking wetlands.
- Using barriers (e.g., fencing) to minimize animal intrusion in the area or to keep species in place and away from the launch location.
- Building new habitat (habitat substitution) or improving existing habitat.
- Implementing an effective lighting policy for management of exterior lights, emphasizing the use of low-pressure sodium lights as opposed to lights that emit ultraviolet, violet-blue, and blue-green wavelengths.
- Active monitoring (and implementing appropriate action plans using the results of monitoring) to offset any unanticipated effects.
- Optimally directing the launch pad flame duct so as to minimize impacts to vegetation from scorching.
- Coordinating early in the proposed project with U.S. Fish and Wildlife, NMFS, and/or state wildlife officials regarding any concerns including: local activities and monitoring of sensitive species (e.g., conducting operations to avoid sensitive breeding, spawning, or weaning seasons).

9.7 Orbital Debris

Although orbital debris is in outer space, it is possible that it could reenter Earth's atmosphere. Likely impacts would be insignificant but the FAA does require applicants to demonstrate certain safety measures in order to receive license approval. While these launch plan features are not required for environmental purposes and the orbital debris outside the Earth's atmosphere are not an impact category, the requirements can have a beneficial mitigating effect. The more orbital debris, the greater the likelihood debris could reenter Earth's atmosphere; and therefore efforts to minimize the amount of debris have an added benefit beyond safety as mitigating detrimental impacts. To obtain safety approval, an applicant must demonstrate for any proposed launch that for all launch vehicle stages or components that reach Earth orbit – (a) There will be no unplanned physical contact between the vehicle or its components and the payload after payload separation; (b) Debris generation will not result from the conversion of energy sources into energy that fragments the vehicle or its components. Energy sources include chemical, pressure, and kinetic energy; and (c) Stored energy will be removed by depleting residual fuel and leaving all fuel line valves open, venting any pressurized system, leaving all batteries in a permanent discharge state, and removing any remaining source of stored energy. Other equivalent procedures may be approved in the course of the licensing process. Additional mitigation measures may be employed to shield against debris particles up to 1 cm in diameter. For debris of larger sizes, current shielding concepts may become impractical.[196] Advance shielding concepts may make shielding against particles up to 2 cm diameter reasonable, but it is possible that the only useful alternative strategy for large particles will be avoidance, which is feasible for average size spacecraft, but for very large spacecraft collision probabilities are sufficiently high that an alternate means of protection may be required.[197]

Launch planning may help to protect launch vehicles and payloads from potential damage. Although there are no measures to significantly modify the current debris environment, there are options available to control, limit, or reduce the growth of orbital debris in the future including:

- Obtaining a conjunction on launch assessment from U.S. Space Command.
- Booster and payload design to minimize release of debris.
- Preventing spontaneous explosions of launch vehicle bodies and spacecraft.
- Use of particle-free propellants.
- Disposal or deborbiting of spent upper stages or spacecraft.
- Careful mission design to actively remove debris.
- Launch vehicles and spacecraft can be designed so that they are litter-free (i.e., they dispose of separations devices, payload shrouds, and other expendable hardware at a low enough altitude and velocity that they do not become orbital).
- Stage-to stage separation devices and spacecraft protective devices such as lens covers and other potential debris can be kept captive to the stage or spacecraft with lanyards or other provisions to minimize debris.
- When stages and spacecraft do not have the capability to deorbit, they can be made as inert as feasible by expelling all propellants and pressurants and assuring that batteries are protected from spontaneous explosion.
- No unplanned physical contact between the vehicle or its components and the payload after payload separation.
- When the mission requires delivery of a spacecraft which itself has a maneuver capability, two alternatives are possible.

1. One is to leave the upper stage attached for delivery of the spacecraft to orbit to maximize its maneuver capability.

2. The second is to separate the spacecraft at suborbital velocity so that the stage decays naturally and the spacecraft uses its onboard propulsion to establish its orbit.

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10. RELATIONSHIPS BETWEEN SHORT-TERM USES AND LONG-TERM MAINTENANCE AND ENHANCEMENT OF THE ENVIRONMENT

Section 1502.16 of the Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act, require that the relationship between short-term uses of man's environment and the maintenance and enhancement of long-term productivity be discussed. For the purposes of this preferred alternative, licensed launches and their associated impacts can be considered as the short-term use of the environment. Each launch involves potential atmospheric, noise, land, water, and biological impacts as discussed in Chapter 5. The ground cloud formed from the ignition of motors and the resulting launch of the LV constitute the main potential impacts. Other potential impacts could result from accidents on the launch pad or during flight. With the exception of atmospheric impacts, impacts to most of these media are short-term in nature. Impacts from changes in pH in soil and water typically recover quickly from acid deposition, depending on local conditions. While adverse impacts to plants and wildlife in the immediate vicinity of the launch pad could occur, species in the local area experience minor impacts or are generally unaffected. Licensed launches may have a cumulative adverse impact on ozone levels in the atmosphere, but ongoing research in this area appears to dispute that conclusion.

Generally, U.S. licensed launches would contribute to the maintenance and enhancement of long-term productivity of the environment in that U.S. launch vehicles generate fewer emissions impacting the atmosphere compared to foreign launch vehicles. As discussed in the analysis presented in Appendix A, a larger proportion of the launches by foreign entities use larger vehicles, which have higher emission rates. Furthermore, for larger payload launches, the U.S. typically uses propellants (e.g., solids, RP1/LO_x), which are associated with fewer emissions of NO_x than the propellant typically used for larger payload launches by some foreign entities (e.g., hydrazine). Licensed launches in the U.S. would contribute to the long-term productivity of the U.S. launch industry and its associated industries, such as telecommunications. Each licensed launch also contributes to the local economy of the launch facility employed.

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11. IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

The licensing of launches would enable transport of government, scientific, and commercial payloads (e.g., communication satellites, other spacecraft, scientific experiments) into various orbits around Earth.

The launch of LVs requires the commitment of natural resources, including the consumption of mineral resources. No additional resources, whether human or land resources, are expected to be committed to the launching of LVs beyond those that have been or will be addressed in site-specific NEPA documentation. Basic commitments of resources for the licensed launch program are not different from those necessary for many other research and development programs. They are similar to the activities that have been carried out in previous space program activities over the past 25 years.

11.1. Natural Resources

Licensed launches would consume various quantities of materials and energy. This section attempts to estimate, where possible, those natural resources which would be committed as a result of these activities.

11.1.1. Material Requirements

The materials used to manufacture LV flight hardware include a modest amount of metals, such as aluminum, nickel, stainless steel, carbon, copper, titanium, and other materials. These materials are readily available in large quantities. Composite materials or FRP (fiber reinforced plastics) are also used on LVs. Composites may be composed of glass, carbon, or aramide fibers imbedded in resin; specific vehicle structural parts or tanks are then fabricated by winding filaments or tape or laying up impregnated cloth or tape as required by the application. In general, the amount of metal and composite materials that would be required for LVs is negligible compared to the quantities routinely produced.

Solid and liquid propellants and other consumable fluids would be expended during the launch of LVs. Appendix A describes these materials and their quantities. LVs typically use solid rocket propellants (such as polybutadiene acrylonitrile and aluminum powder) from launch through both the troposphere and stratosphere. Solid rocket motors in conjunction with liquid LO_x-RP1 systems, or hybrid propellants are also used. During flight through the mesosphere, SRMs, SRMs and LO_x-RP1 systems, hybrid, and hypergolic propellants are commonly used.

11.1.2. Energy Requirements

The energy requirements for launching LVs are mainly for ground-based activities during in-flight support.

No substantial increase in energy demand is expected as a result of launch activity. The ground-based activities would be performed at existing facilities whose energy needs are supplied by existing utilities. Licensed launch activities should cause no substantial increase in energy consumption at these facilities.

11.1.3. Changes in Biological Resources

Biological resources in and around launch facilities will be assessed in subsequent site-specific EAs/EISs. No substantial loss of biological resources is expected as a result of licensed launches.

11.2. Cultural Resources

No substantial changes to cultural resources, employment, land use, recreational and historical resources are expected.

12. PUBLIC AND AGENCY COORDINATION PROCESS

A Notice of Intent was published in the Federal Register on November 27, 1995 announcing the preparation of a programmatic Environmental Impact Statement (EIS) addressing the potential effects of licensed launches. No formal scoping meetings were planned. However, the notice stated that if sufficient interest was expressed in holding a public meeting, those requests should be forwarded to the FAA. Although no interest in holding public meetings was expressed, written comments were received, as summarized in Table 12-1. Comments on the Draft PEIS for Licensing Launches were requested directly from federal agencies, industry, and individuals who expressed an interest in being included on the distribution list. Comments received and responses were included as appropriate in the Final PEIS.

TABLE 12-1
SUMMARY OF COMMENTS RECEIVED DURING SCOPING

Commentator/Name of organization	Issues Raised
Ms. Robyn Thorson Acting Regional Director Department of the Interior, Fish and Wildlife Service	➢ A drawback of the PEIS is the lack of site-specificity. ➢ Analysis of direct/indirect and cumulative impacts should be included. ➢ Should identify that may expect to have facilities built. ➢ Completion of PEIS should not preclude preparation of site-specific NEPA documents and state and local planning.
Col. Louis D. Van Mullem, Jr., USAF Chief, Environmental Management Vandenberg Air Force Base, California	➢ Scope of the PEIS should include payload and payload constituents. ➢ Scope should include ground, air, and water transportation of pre-assembled launch vehicles.
P.K. Arthur Special Assistant for Space WSMR Flight Safety Space Initiative Office	➢ Omit the word "expendable" on the title page. ➢ Is the EIS a site specific document? ➢ This PEIS does not address recovery operations. ➢ For flight-specific applications, use environmental technical documents tiered to the PEIS. ➢ Recommends adopting over land risk criteria prior to completion of the PEIS. ➢ Legal concern over accountability of DOD employees using commercial standards. ➢ Should define the responsibilities or criteria for determining a lead launch site and co-responsibilities of the Air Force Space Range.
Mr. Robert Andreoli WSMR Continued… Mr. Robert Andreoli WSMR (continued)	➢ Should address both expendable and non-expendable launch vehicles. ➢ Consider electromagnetic spectrum usage. ➢ Use cumulative impacts information from WSMR, Holloman AFB, Fort Bliss, NASA, and Space and Strategic Defense Command. ➢ Consider effects of light upon the ability to conduct night space observations. ➢ Consider the reintroduction of the Mexican Wolf into

Commentator/Name of organization	Issues Raised
	southern New Mexico. ➢ Consider effects on local recreation areas. ➢ Consider water use and disposal needs. ➢ Consider air quality pertaining to using optical tracking instruments. ➢ Consider the impact on WSMR operations and land they are using. ➢ Consider present and future air space use by WSMR. ➢ Consider the agreement WSMR has with its neighbors for safety purposes.
Ms. Karen Poniatowski Program Manager, New Programs and Integration NASA	➢ PEIS should be expanded to include environmental effects of a broader number of launches, non-federal government launch sites, a range of payloads, reentry vehicles, reentry of orbital debris, and air-launched vehicles. ➢ The use of "reasonable worst case" to bound environmental effects may not be advisable. ➢ Biological, terrestrial, cultural, and aquatic resource impacts are site-specific. ➢ On page 4-5, the wording and table regarding "fuels" should be "propellants" since oxidizers are included. There should be distinction between amounts of propellants involved or effects of combustion products. ➢ On page 3, 2nd paragraph, a reference to the Army should be included in the last sentence.
Mr. Olin C. Miller Chief, Environmental Flight 45th Space Wing Environmental Flight Department of the Air Force	➢ Can the PEIS be broadened to include generic types of payloads? ➢ Will Evolved Expendable Launch Vehicles (EELVs) be addressed?
Mr. Gregory G.Y. Pai, Ph.D. Director Office of State Planning/Office of the Governor of Hawaii	➢ Issuing commercial launch licenses for any launches in the State of Hawaii should be reviewed for consistency with Hawaii's Coastal Zone Management Program.
Mr. Bill Paulick Alaska Division of Trade & Development	➢ Will the EIS cover platforms such as the Boeing Corp. offshore launch platform? ➢ If the platforms are towed into international waters, will the EIS apply to launches?
Mr. Mike Sirofchuck Citizen of Kodiak, Alaska	➢ It is fair and appropriate to use current information, knowledge, and research in determining suitability. ➢ The licensing of the Kodiak Launch Complex should be delayed until the PEIS is finalized.

13. LIST OF PREPARERS

Project management for the FAA, has been provided by Nikos Himaras and Michon Washington. The following document preparers are employees of ICF Consulting Group, Inc.:

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